MATERIALS & METHODS

THE METALWORKING INDUSTRIES' ENGINEERING MAGAZINE

METALS and ALLOYS

Deep Drawn Magnesium Parts
Radiography With Multi-Million Volt X-Rays
Furnace for Distilling and Refining Metals
Welding Stainless Steel
Diamond Dies for Wire Drawing
Properties of Glass-Reinforced Plastics
Copper Brazing Steel Parts
Air Speeds Powder Metal Forming
Subzero Treatment of Alloy Carburizing Steels
Precision Investment Castings
—Materials & Methods Manual No. 13

MARCH 1946

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METALS and ALLOYS

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Cover Illustration

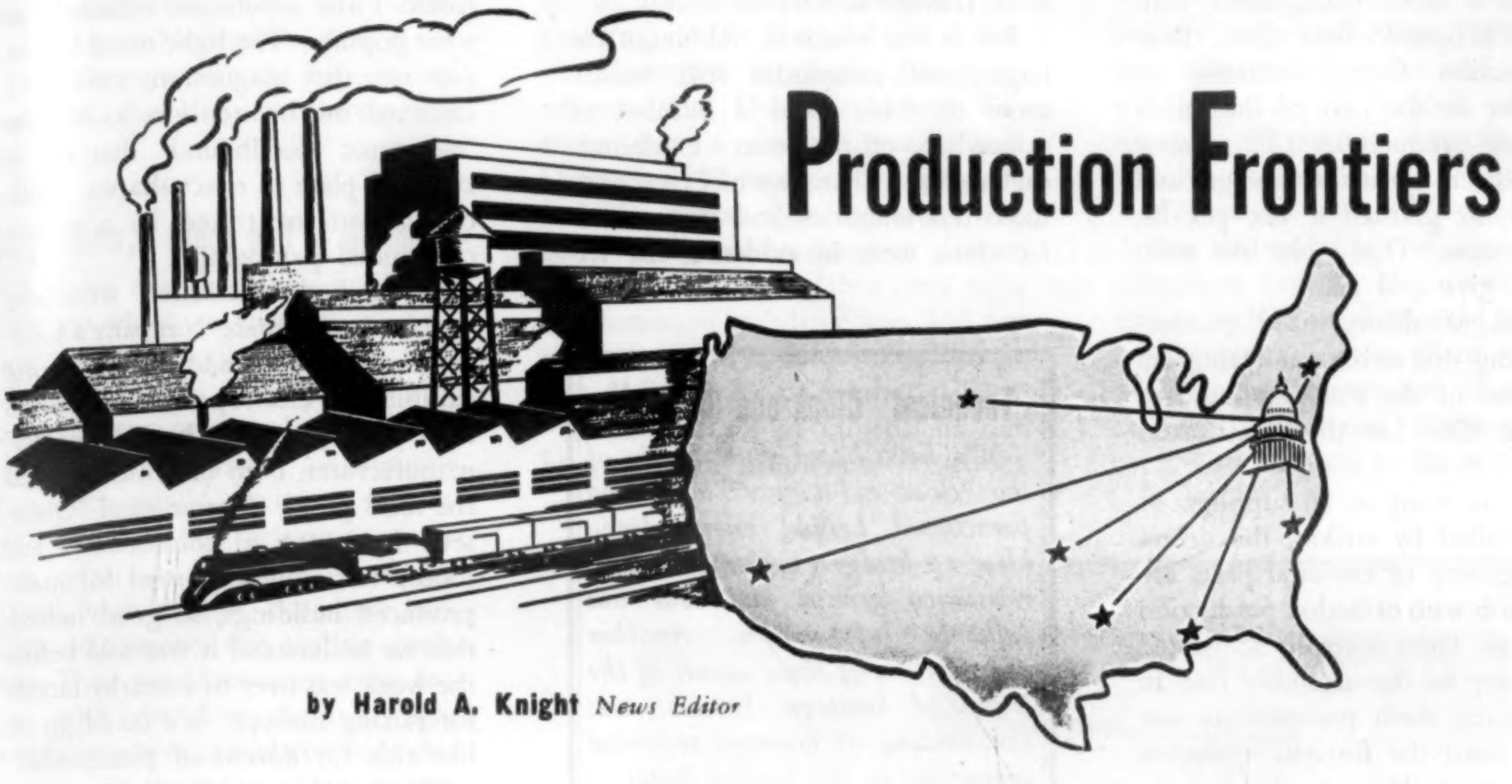
These precision cast parts are representative of those being produced throughout the country. Parts shown are from the plants of Michigan Steel Casting Co., Austenal Laboratories, Inc. and Trifari, Krussman & Fishel, Inc.

NEXT ISSUE:

Plastics as Engineering Materials
Cemented Steel Powder Metallurgy Products
Stress Analysis Methods
Brass Press Forgings or Die Castings
Resin Impregnated Plaster for Tooling
Induction Brazing
High Intensity Gas Heating
Welding Stainless Steel

THE ENGINEERING BRONZES: "Materials & Methods Manual" No. 14

REINHOLD



Production Frontiers

by **Harold A. Knight** *News Editor*

Is U. S. A. becoming a dinosaur? . . . We worry about that pin-point brain. . . . Industrial capacity 65% of the world—we're a colossus. . . . Cart before the horse? High production first—higher wages second? . . . Let F. C. Crawford re-define "Free Enterprise" for us. . . . We hear of one contract where labor agrees on 15% more output. . . . Pullman-Standard engineers daily improvise new methods and unorthodox practices because of "crazy-quilt of deliveries."

Metal Show was perhaps largest industrial exposition. . . . Many precision-castings exhibits and electronic testing displays. . . . "Electronic bloodhound" drew applause. . . . Midgets and "quonset" hut were rival attractions. . . . Housing and feeding much improved over 1944. . . . ASM technical papers of high caliber. . . . Lectures on magnesium, induction heating, stress analysis and corrosion.

We smuggled 116 enemy technical periodicals into U. S. . . . "Magnesium is cheaper per unit volume than any other structural metal except iron." . . . Machining iron takes five times as many man hours as "mag" . . . . When Germans used magnesium it was best material—not "ersatz". . . . Tardily, we report a "new" uranium ruling. . . . "World's largest precision instrument." . . . Foundryman-singer. . . . Automobiles motored by jet.

Topsy-Turvy Period of Our Industrial History

Sometimes we are fearful lest the good old U. S. A. is becoming like the dinosaur—a huge and powerful body, but a pin-point brain. About 85 years ago American factory output was only 25% of the world total. By 1919 we had reached 40%; by 1929, 45%; and now we have attained 65%. Surely we have become an industrial colossus.

But—the way our labor-management relations have progressed and the confused, daily-changing policies at Washington make us wonder just how big the dinosaur's brain was, anyway. Our good friend and Washington correspondent, Paul Wooton, states that it is crystal clear that the Administration wants higher wages and unchanged prices and then he wonders if it would not be more logical to have no wage increases until production is restored. If excessive profits developed they could be reached by taxation. And then Paul concludes:

"But it is not always possible in a democracy to do the logical thing. Democracy inevitably is a compromise between logic and reality."

Speaking of production, at the start of February the Federal Reserve Board index stood at 140, against 164 in December and 235 at the war peak. Surely this is not the glowing post-war situation that had been pictured from speakers' platforms and with charts showing national income, production, etc.!

Free Enterprise Is Human Nature

One of the most pungent industrial speakers is F. C. Crawford, president, Thompson Products, Inc., and executive committee chairman of the National Association of Manufacturers, who usually gets to the homely core of a matter in his economic analysis:

"So much has been said about jobs and wages and so little about production that many of our people have lost sight of their goal. Perhaps the time has come to re-define the American way that has led the world in productivity. *Free enterprise is not a system. It is simply human nature left free to express itself.* It is a composite of consumers seeking better products at lower prices; investors striving for a reasonable return; workers ever seeking higher wages and better working conditions; management constantly striving to increase the rate of production to produce more useful things per hour of human labor and thus creating wealth to satisfy the consumer, investor and worker. This is free enterprise!"

It was refreshing to learn the other

day that a labor-management contract at Eclipse-Pioneer Div., Bendix Aviation Corp., included an agreement on the part of the union to increase productivity 15%. Labor also made a no-strike pledge and management granted a 12c per hr. wage increase. That looks like well-balanced give and take!

Typical of disorganized production during this strike paralyzing era is the case of the Pullman-Standard Car Mfg. Co. Let them tell their story:

"With as many as 16 suppliers at a time stalled by strikes, the delays in the delivery of essential parts are playing hob with orthodox production procedures. Parts normally scheduled for delivery to the assembly line in time for the sixth position are not arriving until the fortieth operation is under way. This chaos takes the dexterity of the works manager, the superintendents and foremen who from day to day must improvise new methods and set up unorthodox practices to obtain orderly manufacturing processes out of the crazy-quilt of deliveries. Acute scarcities exist in the glass, steel, lumber, aluminum, air-conditioning, air brake, roller bearing and upholstered furniture industries."

Biggest—But Was It the Best?

The 1945 Metal Show (Feb. 4-8, 1946) is now history, and sufficient days thereafter have passed for your observer to arrive at what passes with him for detached appraisal. From where we sit it was the biggest, but not necessarily the best ever—remember, however, that this is just one man's opinion and you can doubtless find dozens of persons (total attendance was reported as 50,000) who rated it unequivocally as both the biggest *and* the best.

The Exposition, which displayed the wares (actual or soon-to-come) of more than 350 manufacturers, was unquestionably one of the largest (if not *the* largest) industrial exposition ever held. It filled the whole of the Cleveland Public Auditorium's main arena and labyrinthian underpassages, and even overflowed into catacombs we didn't know existed at all. Three full show-days were required for this finally weary reporter to tour the entire show, making several stops of reasonable duration to oh-and-ah and to chat with friends at various booths.

But it was worth it. Although the large steel companies still remain away in droves and a number of somewhat off-the-beam exhibitors, such as State Chambers of Commerce, industrial laundries and shoe manufacturers, were in evidence, the Exposition was still full of value for all who came.

Technical "Cloak-and-Dagger"

We have heard much lately of the "cloak-and-dagger" boys who parachuted behind enemy lines, blew up bridges, organized native resistance groups and sent out valuable information. Another contribution of these agents of the Office of Strategic Services was the sending of German technical magazines to the United States.

We had a fairly regular subscription to 116 enemy periodicals, totaling 3200 issues. These were placed in the hands of Thomas P. Fleming, now assistant director of Columbia University's libraries, who was then chief of the periodical re-publication program of the Alien Property Custodian.

Important articles were reprinted in German or translated into English perhaps, and distributed to restricted groups of war industries, research organizations and certain libraries. It was Hitler's own policy to allow fairly free distribution of scientific data within German borders. However, much seeped into neutral and occupied countries, whence it was obtained by the "cloak-and-daggers."

We Americans read quite a little on what the Germans had to say on physics and atomic fission. When our technical missions visited Germany they did not find many things unknown to us, after all.

To us, the outstanding feature of this show was the suddenly large number of precision-casting exhibits, some of them extensive, expensive and highly interesting. The electronic testing displays and especially (though not exactly "electronic") the supersonic reflectoscope were popular. The light metal booths (ah me, that magnesium rowboat!) attracted much attention, as did the "electronic bloodhound" that flame-cut steel plate to exact shapes, duplicating patterns traced by a photo-cell-guided pantograph.

Novel and spectacular were one well-known furnace company's hard-working midgets, and the operating exhibit of electropolished stainless steel jewelry put on by a "stainless" manufacturer, both of which crashed the local press. A stran-steel "Quonset" hut was a comfortable and roomy testimonial to steel for mass-produced buildings, so good indeed, that we understand it was sold before the week was over to a nearby farmer for raising turkeys. We could go on like this for dozens of paragraphs.

The housing and feeding arrangements, despite the record-breaking attendance, were much better than in October 1944, and one heard but few complaints. Most everyone who ate in the Auditorium's restaurant had nothing but praise for its excellent food—and waitresses.

For the more technically minded, the fare was excellent, although not as overwhelming (thanks be!) as in former years. With only one large society convening (A.I.M.E. did not collaborate in this show because of its own annual meeting later in the month, but will be back in the next National Metal Congress), it was possible for a man to attend all the technical sessions he wished without emulating all of Gaul.

The A.S.M. technical papers were of high caliber, and the "round tables" were especially to be commended. The educational lectures on magnesium, induction heating, stress analysis and corrosion were highly valuable and well attended. And Dr. Gensamer's Campbell lecture represents a major step along the insufficiently travelled road of research on behavior of metals under stress.

The radiography society put on an active, useful and well-attended meeting. Also well-attended (and of particular interest to editors because the scribes are there the guests-of-honor) were the American Gas Assn's industrial gas breakfast and Jones & Laughlin's annual party for metal-working editorial staffs.

But hold your breath and save your energy—the real 1946 show will be along sooner than you think. The

best information now is Atlantic City, early in November. And if the "1945" Show wasn't the biggest and best ever, the 1946 one surely will be!

Magnesium: Here and in Germany

Suppose that steel was an infant industry while magnesium production had been well established over the past 50 years. Can't one imagine the skepticism over steel and whether it would ever rival magnesium? Pessimists would weigh disadvantages of white hot melting temperature, refractory problems, personnel hazard, high density, expensive handling equipment, the rusting problem. They would contrast these factors with the low melting, light weight magnesium and conclude that steel would never be cheap enough to compete for magnesium's place in the sun.

Such was one of the many intriguing ideas of Dr. J. D. Hanawalt, director, metallurgical department, Dow Chemical Co., who spoke before the Engineering Society of Detroit. Yet magnesium is already cheaper per unit volume than any other structural metal except iron, he said. All of the magnesium made in the world to date could have been taken from about one-tenth of a cubic mile of sea water. Thus, we are depleting no limited resources.

Not many years ago magnesium could not be cast into green sand molds because of burning. Then, accidentally, sulfur as an inhibitor was discovered. Magnesium is less difficut to forge in complicated shapes than aluminum—and is done in fewer steps. Certain single deep draws (60 to 70%) in magnesium would require two or more steps in aluminum or steel.

Just recently a large aircraft fabricator has formed magnesium sheet on a drop hammer instead of a press at great savings in die costs. A maker of aircraft landing wheels says he would need twice as large a machine shop for aluminum. As to magnesium die castings, one manufacturer lists machining costs as 25% higher for aluminum castings, 35% higher for bronze and 50% higher for cast iron than for "mag."

Engineers of a German automobile maker have said that in machining iron it requires five times as many man-hours as with magnesium. Using special machines, "Volkswagen" engineers found it needed 2 hr. to finish aluminum for 1 hr. for magnesium. The Douglas Aircraft Co. states that a finished magnesium I-beam is 25% cheaper, 35% stronger and 5% lighter than the aluminum beam it replaced. Another aircraft company found that labor costs with an aluminum stabilizer was $40 for material and $191 for labor as against $62 and $78 for magnesium.

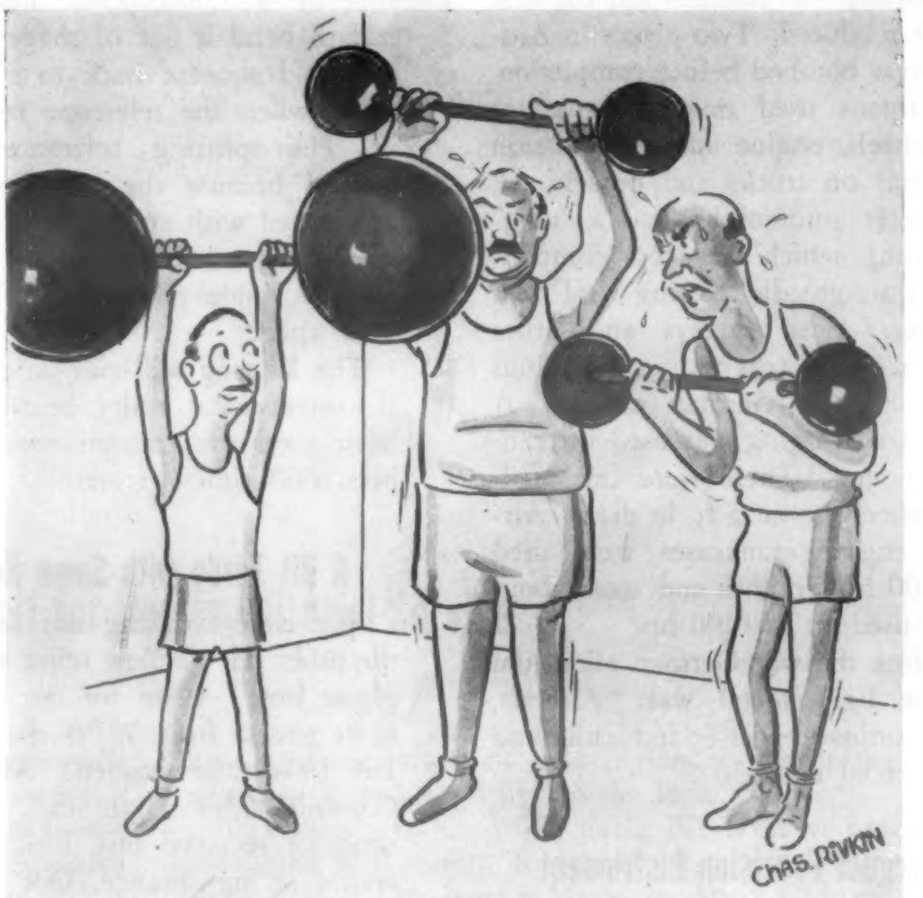
If an increase in dimensions can be permitted, magnesium structures can be more rigid than competitors despite the fact that the modulus of "mag" is 6½, of aluminum 10 and steel, 29. Thus, magnesium is suitable for high-speed planes where aerodynamic efficiency demands exact shape of surface with no flutter. With the thicker sections the shell is stronger and does not need internal supports.

There is perhaps more misunderstanding about the corrosion stability of magnesium than any other property. This may be due to lack of adequate definition of exposure conditions. In average atmosphere it is very stable. After 15 years bare magnesium parts will have formed a gray adherent oxide coat and at most will have lost 10 to 15% of their strength. If painted correctly there will be no loss.

Magnesium received a black eye during the early days of casting development because of corrosion due to flux inclusions, eliminated in present foundries. Again, there was too much indiscriminate use of accelerated salt water tests. Magnesium is even more resistant to sea water than some other metals, such as ordinary steel.

A not well-known property is its "resilience," or measure of ability to absorb impact energy elastically as distinguished from plastic deformation, thus allowing it to stand more abuse in the serviceability range, with less damage by permanent deformation than either aluminum or steel.

Dr. Hanawalt spent considerable time in Germany last summer. He explodes the idea that Germany used magnesium because she lacked other metals. He says that magnesium had



Superman, Nuts! He's a magnesium products designer.

to face strong competition from other metals, particularly aluminum. Hence, "mag" was used where it was the best material for the purpose. In 1938 the German textile industry used 300,000 lb. every month, more than total consumption in the United States then.

Magnesium production in Germany was one-tenth that of aluminum. Her main production was from dolomite. Germany, because of the lack of electric power, cannot be called a "natural" country for either magnesium or aluminum. During the war her main production was in Norway and Austria. But the plant in Norway was bombed flat the first day it produced. Two plants in Austria were bombed before completion.

Germans used much magnesium for wheels, engine and transmission housings on trucks and busses. All passenger automobiles had a "mag" oil pump which was cost competitive through die casting and machining. Fans, pulleys and other parts were of magnesium. Forgings were used in German aircraft. A very large forging was used for cannon mounts. There were cast artillery wheels, some 5 ft. in diam. Aircraft engine crankcases were used for 700 hp. engines and were about to be used up to 1400 hp.

Before the war German allocation of the light metal was: Aircraft, 40%; ordnance, 30%; industrial and commercial uses, 30%.

Largest Precision Instrument

Scientists of the California Institute of Technology are back at work, come peace, completing the world's largest telescope, the 200-in. lense installed atop Mt. Palomar in California. It will let astronomers peer 1,000,000,000 light years into space.

This world's largest precision instrument has a 500-ton mounting, supporting the 200-in. mirror and optical system, the entire structure having the proportions of a 6-story building. Despite its size the whole assembly revolves with such frictionless smoothness that a motor under ½ hp. could actuate it.

Some ticklish engineering problems were involved. Toughest was the fabricating and machining of the 317,000 lb. horseshoe bearing on which the telescope rides on its tour of the skies. The bearing was shipped via three freight cars from Westinghouse's S. Philadelphia plant to East Pittsburgh, where the world's largest boring mill was enlarged further to 44 ft. diam. The bearing's steel was pared off until the bearing was within five one-thousandths of an in. of a perfect circle.

More trouble in the form of the sun's rays through the shop windows! Each 4 p.m. the bearing began to swell, sometimes as much as thirteen-thousandths of an in. At night it contracted. At length engineers built a "sunbonnet" around the bearing that reduced temperature fluctuations by 50%.

Then, because the bearing must support a 1,000,000-lb. load, they had to bend it out of shape so that it would squeeze back to a perfect circle when the telescope rested on it. Hair-splitting tolerances were needed because the telescope must be sighted with an angle of error so small that at 3 miles two lines drawn from a single point would be only 1 in. apart.

The bearing will run on oil pads. If conventional roller bearings had been used the friction would have been 600 times greater.

A Bit Tardy with Some News

We were cleaning out our desk the other day (fellow office workers, please note) when we ran across a news release from WPB, dated Aug. 16, 1944 and headed "Allocation Controls Over Uranium." At the time we received this, little did we realize its significance. Our sense of news values went haywire, for we did not deem it of sufficient importance to publish. Give us credit, at least, for not throwing it into the wastebasket.

The gist of the notice was that sales of uranium, its alloys, etc., for certain uses then continued to be forbidden and the WPB was to henceforth allocate all other sales and purchases in lots of 10 lb. or more. Any person having in his possession 2,000 lb. or more of any ores containing five-hundredths per cent or more of uranium oxide should file the information with WPB.

Then it goes on to say that in normal times uranium, "now a critical metal," is used in the manufacture of glass, glassware, pottery, tile and other ceramic products; also in the processing of photographic plates, films and papers. We wonder if that tile in our bathroom is radioactive and if we'll suffer the fate of the Japanese who did not die at the original blast at Hiroshima?

Foundryman-Singer

Gypsy Rose Lee notwithstanding, it is always interesting to find hidden talents among the great. It took a Big Three meeting, for instance, to reveal that our own Harry S. Truman is a piano player, who tickled off some sweet ivory music in front of Stalin, et al. A former vice president and financial wizard, Charles G. Dawes, not only played the piano but composed a lively ditty that is a living masterpiece.

And now we see by *The Foundry*, our esteemed contemporary, that none other than Boo-Boo Bing Crosby is a foundryman. Yes, sir, he is part owner, along with his brother, of the Major Aircraft Foundry Corp., Puente, Calif. There he is, depicted in a photograph in front of a blueprint in that foundry, pointing out with pencil certain features of the drawing.

We can imagine him saying to brother Larry: "I'd put a chill in here and you'll get hard Martensite along the surface that will resist abrasion. Throw out those chaplets you've been using and try one made of Monel. That resists corrosion of the gases."

Our surprise has been so great at this discovery that we are in utter confusion. Let's see—didn't Bing cast those "Bells of St. Mary's"—cast them in his foundry? Wasn't he cast for a part in the movies, too? First thing you know, he'll be more famous as a sandcaster than as a singer.

Automobiles Motored by Jets

Certainly there are many spectacular things just around the corner for jet propulsion. We were among a group of high temperature alloy people and aeronautical engineers the other night and they predicted that in 10 or 15 years the average automobile will be run by a gas turbine. The disc would be 3 or 4 in. in diam., with blades about 1 in. long. This will be another step toward the goal of a 100-hp. engine weighing only 100 lb.

The best prewar material in turbine blades had a life of only 100 hr.; the next development brought life to 1000 hr., the next to 1500 hr., and a more recent one, to 9000 hr.

EDITORIALS

A Bigger Staff for Better Editorial Service

Modern industrial magazines must have large staffs of able, informed writers if they are to provide a steady flow of useful and interesting articles to satisfy the specialized technical needs of their respective readerships. Through the return of two of our editors who were on military leave-of-absence, and other recent additions to our staff, this magazine is now better equipped than ever before to provide the metalworking industries with alert, comprehensive and detailed coverage of developments in engineering materials and processing methods, and on a nation-wide basis.

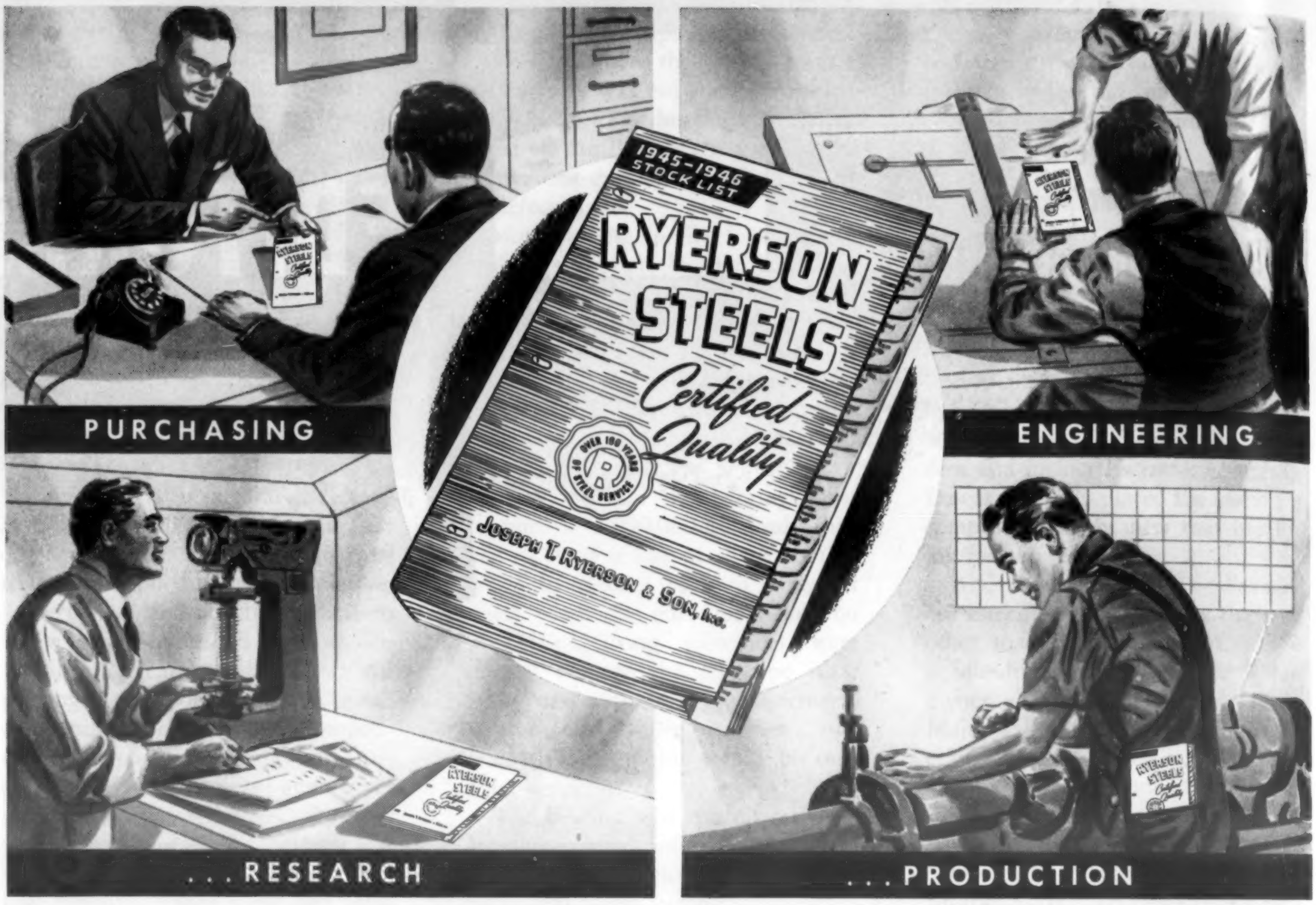
During the past few weeks we have happily welcomed back to the staff two members who have been serving in the Armed Forces—1st Lt. Henry R. Clauser, who has been with Army Ordnance since July 1942; and Lt. Robert S. Burpo, Jr., who has been with the Navy since April 1943. They resume their duties as Associate Editors, with headquarters in New York.

Our Engineering Editor, Kenneth Rose, will henceforth have his headquarters in Chicago, 22 West Monroe Street. With this move MATERIALS & METHODS will be much better able to provide quicker coverage of new technical developments originating in the prolific Midwest area, than we have been in the past, and will also be assured of on-the-spot editorial representation in that region to match that which we have always had in the East.

To represent us editorially in the Far West we have appointed E. K. Smith, for eleven years with Electro Metallurgical Co., later a Major in Army Ordnance for two years, and now a consulting metallurgist on the West Coast, as our Western Correspondent. His office will be at 205 South Crescent Drive, Beverly Hills, Cal. Mr. Smith, with an enviable reputation and acquaintance among metalworking engineers and metallurgists, will undertake to keep our readers informed on materials-and-methods developments originating or interestingly applied in Far West plants.

Herbert Chase, well-known technical writer, specialist in the field of parts-engineering, wartime editor of the Government-sponsored aircraft-shop magazine "Wings," and already a familiar name among our authors, officially joins the staff as Contributing Editor. This arrangement will assure our readers of the best possible all-around coverage of the interesting and increasingly important problems of selecting production methods for small parts and related topics.

These additions are aimed to intensify and improve our service to you. Won't you let us know how you like that service—where it is weak as well as strong—so that we may take intelligently directed steps to make it even better in the future? —The Editors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OVER 100 YEARS
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JOSEPH T. RYERSON & SON, INC.
. . . RESEARCH
. . . PRODUCTION

Radical vs. Conservative Automobile Design

"You see, the post-war automobiles are not the razzle-dazzle Rube Goldberg creations of the wonderful new post-war world the dreamers had predicted. They have been following very closely the models of 1941, except they have a few more pounds of chromium trim over the front bumper."

That was the gist of a piece in one of the retail sales house organs of the Chrysler Corp. a few months ago.

But wait! Perhaps that observation was a little premature. We ourselves saw the new automobile engine of Crosley Motors, Inc. at Cincinnati, made mostly of steel stampings brazed together. Surely that is something radical, and perhaps our readers will be riding around in those little 50 miles-per-gallon cars by the time this reaches print.

Other automobile engines are being built chiefly of die-cast parts. That is something radical, too. Foresighted automotive engineers have been predicting some interesting things. One asks why must an easy-riding automobile average 3000 lb. in weight? Why can't an automobile be just as easy riding at 1000 lb., if designed and balanced correctly and provided with vibration-dampeners against road shocks and movements. As one engineer expresses it, if one must have extreme-heavy weight for easy riding, why isn't a truck easier riding than a baby carriage?

Another knowing automotive engineer predicted back in war days: When a radical automobile is brought out it will be by some comparatively new and daring entrepeneur—not by the conservative old line companies who will be inclined to stick to time-tested designs.

So it is perhaps wise to watch companies such as Crosley, Kaiser-Frazer, etc. Already enough rumors come out of Detroit and other auto centers about plastic bodies, fiberglas-plastic fenders, engines in the rear, etc., to suggest that the chances for radical departures are by no means dead. Look how jet propulsion is revolutionizing the airplane. Interesting days are ahead for automobile design and materials!

—H.A.K.

Since You Went Away . . .

Three years is a long time to be away from one's desk. A great deal has happened during that interval. The annual Engineering Review numbers of METALS AND ALLOYS and, later, MATERIALS & METHODS, attest to the magnitude and scope of changes in the fields of engineering materials and processing methods.

Alloys for high temperature service, plastic materials, new substitute materials, new processing methods, new and better finishes and finishing processes have been introduced and become commonplace. Many manufacturers have learned to produce large numbers of war-necessary parts to rigid specifications and dimensions so that they are interchangeable with like parts made by other manufacturers.

Prewar thinking in this line is mirrored by a current advertisement for a popular brand of fountain pens which bears the legend "Why —— pens can never be 'mass produced' . . . . ." Then this ad goes on to state that the component parts of the pen are formed to dimensions having maximum tolerances of plus or minus 0.001 in. It is too bad that these advertising people have not yet learned about the hundreds of factories turning out parts for bombsights, aircraft superchargers, aviation engines, machine tools and gun parts—millions of these have been made having the aforementioned ($\pm$0.001 in.) or narrower tolerances. One of the most important war-taught lessons was the mass production of interchangeable parts to very close tolerances and with very accurate control of surface finish.

Yes, there have been great and far-reaching improvements and changes in both materials and processes "since you went away."

But what about the field of human relations? Can we get along with our employees or our employers? Have relations between United States citizens of different colors and creeds improved?

To return to civilian life and find people attempting to legislate tolerance and understanding (by means of such devices as various antidiscrimination bills) is a sad commentary on our civilization. The art of human understanding, the field of human relations, seems to have deteriorated rather than improved.

Friction, intolerance and bad faith between groups cannot be banished by legislation. Both parties to such controversies must each build up in the minds of the other confidence, trust and mutual respect. One is tempted to ask—have certain minority groups, certain labor unions, certain employer organizations, certain religious groups conducted themselves so as to inspire confidence, trust and respect on the part of others?

Our strides in the field of materials and process engineering have been stupendous during the war years; the field of human relations (some people prefer to call it "human engineering") lags far, far behind in development.

—R.S.B., JR.

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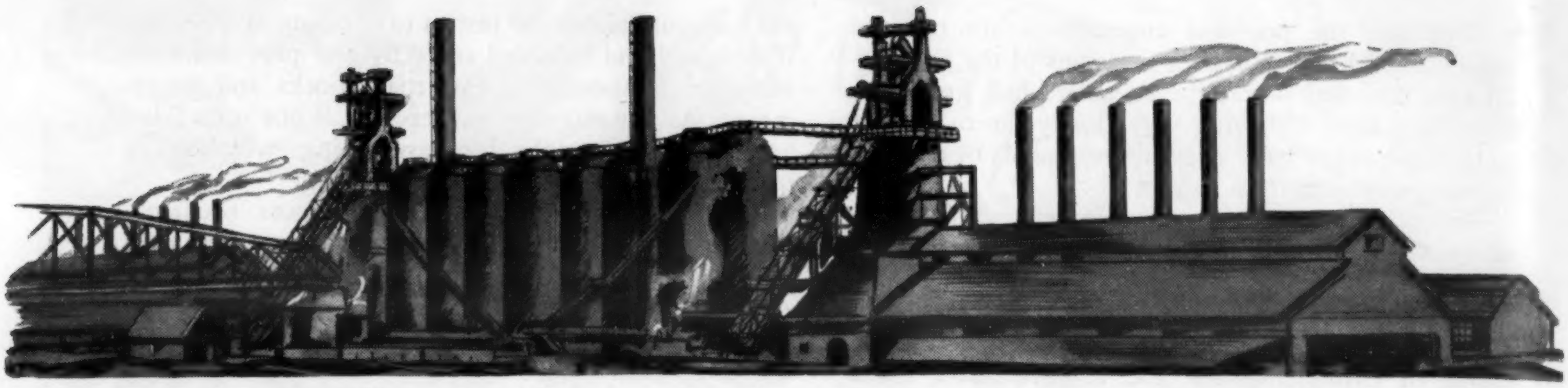
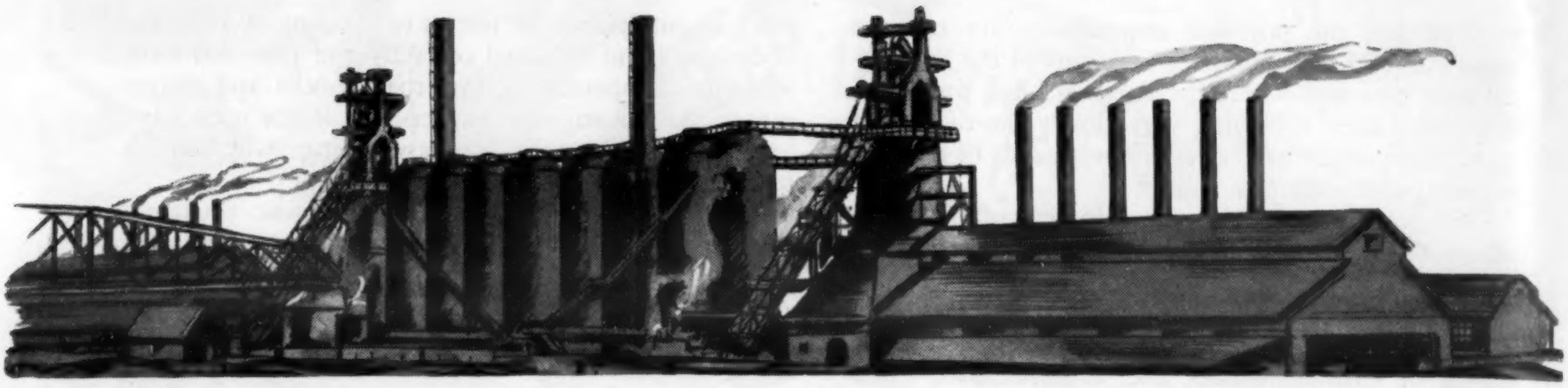
—R.S.B., JR.





Research—Bottleneck of Our Future

an Editorial

We are not a research journal. But the industries we serve and more particularly the engineers to whom we cater therein depend for their future growth and prosperity, their future materials, processes and products on the results of today's scientific and technical research. And the future position of this country as an international economic or military power (which is another way of saying our future existence) is a direct function of the state of technical advancement of the metalworking industries—the industries that make, among other things, atomic-energy materials, electronic equipment, aircraft and production machinery.

For these reasons we, in company with many others, are genuinely concerned about the present-day paucity of research personnel and the general "so what?" attitude toward a National fundamental-research program. The "paucity" is not of experienced older research workers and directors, but rather of young, college-trained scientists and technicians who will be the research leaders of the future. This scarcity, bordering on an absence, of young scientists can be blamed directly and exclusively on our tragically shortsighted wartime Selective Service and manpower policies. No other international power was so blind to its own national interest during the war as was America in virtually forcing its colleges to discontinue regular graduate and post-graduate work in the fundamental sciences and to abandon their own basic research programs. Russia and Germany carefully provided for continuance of both fundamental research and college training of scientists at a rate at least equal to pre-war levels, while England and even France arranged to keep a substantial number of future research workers studying in their colleges.

The case of Russia is particularly challenging. According to all reports and because of the Soviet's wartime maintenance of research and of research training, that country is emerging as a new power in international science and, if the present trend continues, may soon topple the United States from our present position as the World's technological leader. Such a development might have serious, even disastrous, implications for us. But even if we forget any competitive situation vis-a-vis Russia, the latter's wisdom in insuring its future technological progress still reveals by contrast our own foolhardiness.

What can we now do to remedy this situation? Obviously we cannot immediately fill the present gaps in our ranks caused by our wartime errors. But we can redouble our efforts to catch up as rapidly as possible and then to place this country on an entirely new basis, scientifically speaking, to assure our continuing leadership in this technological world. Specifically:

(1) We can make the rewards and compensation for research work more substantial than they have been in the past, so that able investigators and technicians will not be forced to turn reluctantly into more remunerative fields;

(2) Industry—either as individual companies or cooperatively—can provide wholesale financial support of fundamental research in the basic sciences of various industrial fields, either by large grants to existing institutions or by establishing new research institutes just for this pur pose; and

(3) All of us should support the Bush plan as embodied in pending legislation for Federal support and subsidization of fundamental research on a National scale. Such a program does not mean the Government "takes over" research; it merely sets the Government up as one of the groups financially fostering a research program with its own long-term interest at heart.

America will be a "has-been" in 1970 if we don't break the research bottleneck confronting us in 1946!

FRED P. PETERS

David Basch

Charles W. Parker

R. A. Wilkins

Clyde Williams

O. W. Boston

J. B. Johnson

R. H. McCarroll

The Panel of Judges for the

1946 MATERIALS & METHODS ACHIEVEMENT AWARD COMPETITION

A distinguished list of outstanding engineers has accepted the invitation of the Reinhold Publishing Corp. to serve as judges in the 1946 Achievement Award Competition.

These engineers, all leaders in their chosen fields of activity, are eminently qualified to judge such a competition as MATERIALS & METHODS is sponsoring. The judges and their affiliations are:

DAVID BASCH, Almin Ltd., (Britain), Schenectady, N. Y.
O. W. BOSTON, Chairman, Department of Metal Processing, University of Michigan, Ann Arbor
J. B. JOHNSON, Chief, Materials Laboratory, ATSC, Wright Field, Dayton, Ohio
R. H. McCARROLL, Director of Engineering, Ford Motor Co., Detroit, Mich.
CHARLES W. PARKER, Secretary, Committee on Manufacturing Problems, American Iron and Steel Institute, New York
R. A. WILKINS, Vice President, Revere Copper & Brass Inc., Rome, N. Y.
CLYDE WILLIAMS, Director, Battelle Memorial Institute, Columbus, Ohio

Fred P. Peters, Editor-in-Chief, MATERIALS & METHODS, will serve as non-voting Secretary

The subject and conditions of the 1946 Achievement Award Competition were announced in the January 1946 issue of MATERIALS & METHODS. This year's award is to be made to the company, group of individuals or individual judged to have attained the greatest achievement in applying war-born knowledge of materials and their processing to the manufacture of peacetime products.

Entries are to be received through June 30, 1946, and the award made during the week of the National Metal Congress.

Fig. 1—This part, difficult to draw in aluminum alloys, was formed in one operation from magnesium alloy.

Production Principles for Deep Drawn Magnesium Parts

by **RALPH G. GILLESPIE,** *Brooks & Perkins*

Difficult to draw or form when cold, magnesium alloy becomes readily workable when properly heated and dies are designed to meet magnesium's requirements.

DURING THE WAR it became necessary to decrease to an absolute minimum, without undue loss of strength or functional requirements the weight of all aircraft components and airborne equipment. This led to an unprecedented increase in the use of magnesium sand castings, die castings, extrusions and formed and deep drawn sheet magnesium parts.

Many manufacturers quickly saw the advantages of using deep drawn sheet magnesium for numerous civilian products. Adding machines, typewriters, and radios can be made with drawn magnesium cases. Other logical applications are housings for portable tools, cameras, vacuum cleaners and washing machines, and filing cabinets, luggage, tool boxes, milk bottle crates, bread delivery crates, baby buggies, wheelbarrows, children's toys, medical and X-ray equipment, and movie projectors. Wherever weight reduction is necessary, magnesium should be considered.

Although magnesium is the easiest of commercial metals to machine, it is very difficult to form or cold work at room temperatures. In this respect it resembles zinc. Magnesium, like zinc, has a hexagonal crystal structure. When drawing any metal the flow of the metal is on "slip planes." So, the drawability of a metal depends largely upon the number of these planes available for slip. Magnesium alloys, being made up of close packed hexagonal crystals, possesses

fewer slip planes than other metals such as copper and aluminum. This in turn causes the metal to very quickly crack or break by becoming overworked. At temperatures up to 400 F magnesium has only one set of slip planes. At a temperature of 400 to 450 F the pyramidal planes become active, and in the temperature range of approximately 450 to 650 F it is possible to do in a single draw what would require up to three drawing operations in any of the cubic crystal systems, such as steel, brass, or aluminum.

Although the price per pound of rolled sheet magnesium alloys is somewhat higher than that of other metals, the difference in weight together with lower fabrication cost for deep drawn parts, where one draw is substituted for two or three draws with intermediate anneals when other metals are used, brings magnesium into a favorable position in regard to price.

Deep drawing of magnesium does, however, present numerous problems and it can be successfully done only (1) when the die, punch, and blank are at the proper temperature; (2) when a suitable lubricant is used on the blank and on the die; and (3) when the press pressures and speeds are properly regulated. There are also special considerations in die design for deep drawing magnesium.

Part Design

In general, any design which can be drawn from sheet steel, sheet aluminum, or sheet copper or brass, can be successfully drawn from magnesium. In fact, some parts which either cannot at present be completely drawn or would be extremely difficult to draw from other metals can be drawn from magnesium. The gun fairing shown in an accompanying illustration is an example of a part which was found to present excessively difficult problems using aluminum alloys, but which was easily drawn in one operation from magnesium alloy. The same is true of the top corners (roof corners) of large buses which have in the past been partly drawn from sheet steel then finished by power hammering to shape. They can be completely drawn in one operation from magnesium alloy, with a significant reduction in labor cost.

Hemisphere or cylindrical shapes have been drawn to a depth of about two times the diameter in one draw. Rectangular box shapes have been drawn to a maximum depth of 1½ to 1¾ times the narrow width in a single draw. This may not be the ultimate limit but at present represents the approximate limits which are commercially feasible, using one draw.

Of course, the size of the corner and bottom radii are also determining factors in regard to depth of draw. Box shapes should be designed with corner and bottom radii larger than three times the thickness of the sheet. This generalization, however, is subject to so many exceptions that it is not a very valuable guide. How low we can go in the size of radii is one thing that no one yet knows. Careful control of other conditions may make it possible to go to limits not now even considered. At present, we prefer inside corner radii of ½ in. or more, and we have gone somewhat under ¼ in. on bottom corners. Several designs of radar computor cases were made during the war, with 11/64-in. inside radius at the bottom.

Such a case is illustrated. The case and cover were each made as a single draw, after which the holes were blanked. A strip of thin sheet magnesium was spot welded at the top of the box (inside) to form the flange for the cover. Then the threaded tubes and clips were welded in by heliarc welding. The finish is a dull black inside and a black crackle finish

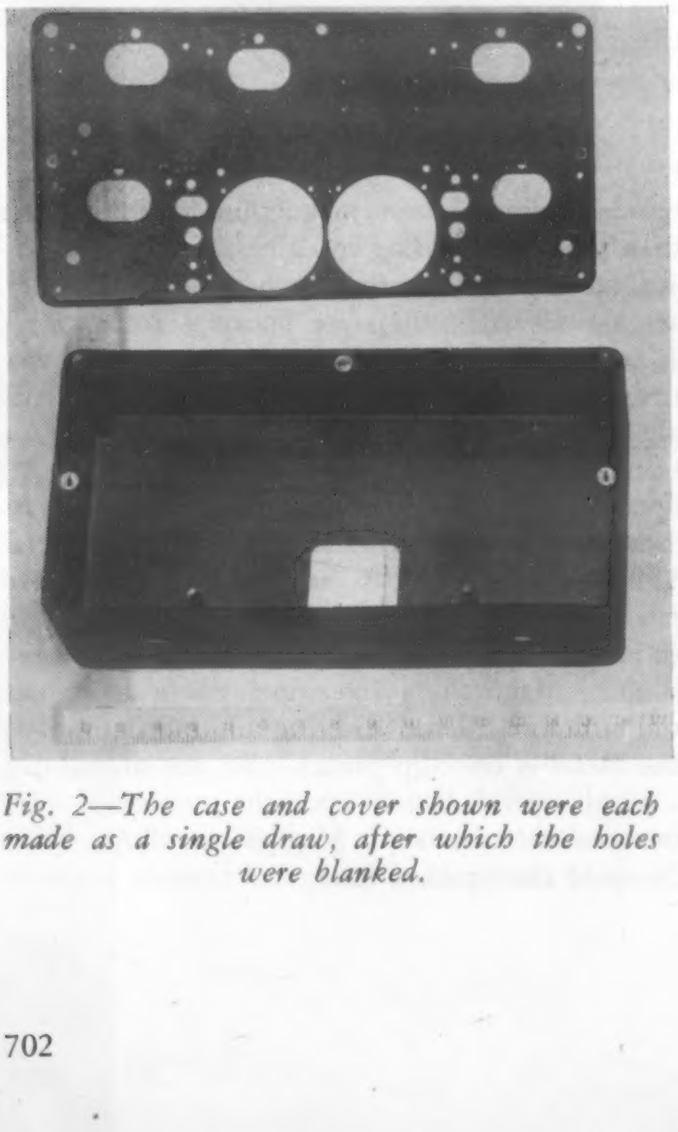


Fig. 2—The case and cover shown were each made as a single draw, after which the holes were blanked.

Fig. 3—By being made from magnesium alloy, this case was formed in one draw, rather than from welded sheet as was previously necessary.

on all outside surfaces. Both finishes are baked-on.

A large radar computor case, was 26 in. long by 16⅛ in. wide, drawn to a depth of 11 in. The material is 0.064-in. thick. One side of the case has a 45-deg. inclined surface starting 5½ in. from the top edge. Cut-out sections were routed after drawing. Before being made from magnesium alloy by a single draw, this part was made from sheet aluminum, with welded construction.

Another illustration shows a dorsal fin used on the Republic P-47 Thunderbolt. Both the untrimmed fin as drawn and the trimmed fin are shown. Although the untrimmed fin is in excess of 61 in. in depth, it is so light in weight that a girl can hold it with little or no effort. The material is 0.040-in. thick and the radius at the bottom of the drawn crease is only ⅛ in.

Drawing Dies

Drawing dies for magnesium are usually made entirely of mild steel. However, the punch can also be made of cast iron, aluminum, or magnesium. Tool steel is often used for the draw rings and pressure pads, although because of its higher cost, use of tool steel is not justified except for high production dies. Surface hardening of the dies by nitriding, or adding a hard chromium plate can help to diminish pick-up, which is sometimes a serious problem, although at present dies are not usually so treated and pick-up is controlled by lubrication of both blank and die.

The design of drawing dies for magnesium is much the same as for other metals. The differences are those which are involved in the necessity for heating the die, and for providing for the differences in coefficient of expansion of the heated die and the heated magnesium. It can be readily understood that because of these factors the amount of clearance must be carefully calculated and the temperature at which a given die is operated must be controlled within reasonably close limits. Steel expands about ⅓ as much as magnesium for the same temperature rise. For this reason steel dies must be made somewhat oversize. All steel die dimensions should be multiplied by a factor of 1.0040 if the drawing temperature is 600 F. Clearances between the male punch and the female die should never be less than the metal thickness and in the case of deep draws should be somewhat more than metal thickness, as the compression causes a thickening of the metal during drawing. For deep draws the clearance should equal about 0.30 times the metal thickness being drawn, plus the thickness of the blank.

The thickness of plates used for draw rings and pressure pads should be sufficient to avoid danger of distortion when heat is applied. For this reason, plate less than 1.5-in. thick is not used. The radius of the draw ring affects the drawability of metal. Magnesium sheet has been drawn with draw ring radii from 4 to 15 times the sheet thickness but for most deep draws,

Fig. 4—Dorsal fin for Republic P-47 Thunderbolt. Its lightness is demonstrated by the ease with which the girl holds it.

best results are obtained if this is held to a minimum of eight times the thickness of the sheet. The use of too small a radius increases drawing resistance and limits the depth of the draw. On the other hand, if too large a radius is used, there is a greater tendency to pucker the metal during drawing.

The pressure imparted to the blank by the pressure pad must be closely controlled. Sufficient pressure should be used to prevent wrinkling, but if too much pressure is used, the sheet cannot be drawn between the clamping surfaces. This will result in rupture, or at least thinning of the drawn part. Clamping pressure is usually determined and adjusted experimentally during die tryouts.

Dies may be heated by using either electric strip heaters or open gas flame. Gas heating has been the most commonly used method, although the trend now is toward increasing use of electric heating. For gas heating the burner usually consists of a standard ¾- to 1½-in. pipe with one or two rows of No. 40 holes on ½- or ¾-in. centers. If two rows are used, the rows are usually spaced about ¾ in. apart. The pipe can be bent to shape to be used under the die between the punch and die (removable pipe) or around the edge of the die ring. Wherever it is possible to do so, we favor a fixed installation of such heaters around the outside of the die ring. However,

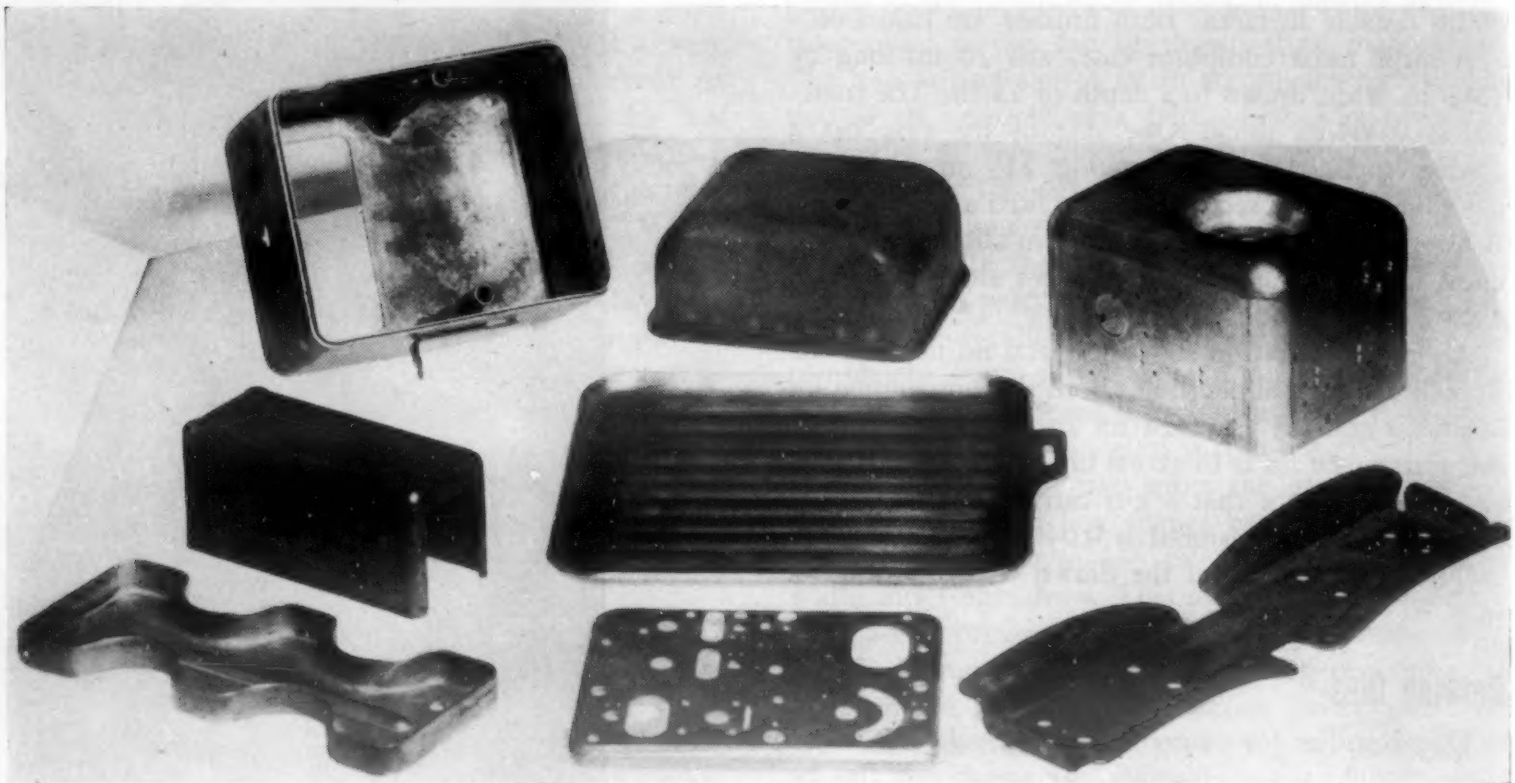


Fig. 5—A group of typical parts drawn from magnesium alloy.

the location of heaters would necessarily vary with differing heating requirements for various types of draw. It is always desirable and usually necessary to have the heaters, whether gas or electric, thermostatically controlled. In this way it is possible to control die temperatures to within ±5 F.

Temperatures

Annealed blanks can be drawn at temperatures varying from 400 to 650 F (or even 700 F if alloy MA is used). Alloys having low melting point constituents should be kept at 600 F or less. Hard rolled metal such as M-h and JS-1h must be drawn at lower temperature (about 400 F).

FS-1h starts to anneal at about 300 F. These alloys in the hard condition are usually where strength is the important consideration, and any drawing temperature at or in excess of the recrystallization temperature will anneal the metal and result in a loss of yield and tensile strength. This, of course, limits the depth and severity of the draw possible with such metal.

When deep drawing annealed blanks it is possible to control thickness of the finished part somewhat by closely controlling the drawing temperature. For instance, if a part is found to be slightly over the limits of tolerance when drawn at 550 F, an increase in temperature to 600 F or more will result in greater shrinkage of the part upon cooling and in more expansion of the dies at drawing temperature. This will result in a decreased finished part dimension and will bring it within the desired limits. The wall thickness at the sides and bottom of the drawn part can be maintained and thinning of the section prevented by using a hot blank and die with a cooled punch. Using a cooled punch permits the hot plastic metal to be drawn over the draw ring radius but to be cooled by the punch, which also increases its tensile strength.

Lubricants

Temperatures involved in drawing immediately rules out the possibility of using ordinary oils or greases as lubricants for either the die or the blank. The best lubricant for blanks so far used for deep drawing of magnesium alloys consists of a small particle colloidal graphite dispersion in lactol spirits (a low boiling point naphtha). This is sprayed on the blank before the blank is heated. The lactol spirits evaporate quickly leaving a film of graphite. The die is lubricated by applying a mixture of graphite in tallow. The only objection to this type of lubricant is the difficulty encountered in removing the graphite from the formed part. Cleaning is accomplished by dipping in a chromic and nitric acid solution which does not affect the graphite but which etches the metal slightly and loosens the graphite film. At best a certain amount of hand cleaning is involved. Fabricators are experimenting with various lubricants and it is hoped that a material will be found which can be more easily removed without sacrifice of the advantages of the graphite lubricant.

For shallow draws at temperatures of 525 F or lower we have found aluminum forging oil to be quite satisfactory and to be easily removed from the

work. This oil is applied to the die ring once every 10 to 20 blanks and no lubricant is applied to the blank.

Pressures and Speeds

The pressures and speeds which can or should be used to deep draw any part are usually finally determined by try-out. The highest pressure that can be used is the pressure which will rupture the blank. Since work hardening depends on the velocity of deformation at a given temperature, the optimum drawing speeds can be determined by actual trial. Magnesium "can be severely drawn by working at an elevated temperature and at a critical speed coincident with its recrystallization rate" according to *Forming and Drawing Revere Magnesium Alloys.*

It has also been observed by fabricators of magnesium alloy that increasing the speed of drawing at a given high temperature produces an increase in tensile strength.

Choice of Alloy

Magnesium alloys, obtainable in sheet form and now most commonly used for drawing, are M, FS-1, and JS-1. Alloy M is magnesium with 1.5% manganese. It is the lowest in price and has the best deep drawing characteristics. It can be welded easily by either gas or arc methods. The thermal and electrical conductivity of M alloy is higher than of FS-1 or JS-1, but mechanical properties are lower.

Alloy FS-1 is magnesium with 3.0% aluminum, 1.0 zinc and 0.2 min. manganese. Alloy FS-1 has slightly poorer deep drawing qualities than M, but has superior forming qualities. Weldability is somewhat less but mechanical properties are higher than M and only slightly lower than JS-1.

Alloy JS-1 is magnesium with 5.0% aluminum, 1.0 zinc and 0.15 min. manganese. This alloy offers the highest mechanical properties combined with excellent welding characteristics. Its drawing and forming qualities are not so good as either M or FS-1.

Where price is important and high strength is not required alloy M should be used. If higher strength is required and very little welding is to be done, FS-1 should be considered. If maximum mechanical properties are desired and the draw is not deep, JS-1 should be used.

Finishing

As higher purity wrought alloys have become available corrosion is not the serious problem it once was. Magnesium alloy is more resistant to atmospheric corrosion than is ordinary iron or steel. However, when in contact with other metals galvanic corrosion can be serious. Most drawn magnesium parts are used in the pickled and painted condition or in the anodized condition.

The chromic acid pickle treatment furnishes an excellent surface for primers, paints, lacquers, and enamels. The anodize treatments developed by Dow Chemical Company (Dow Treatment No. 12), and by Consolidated-Vultee Aircraft Corporation (Manodyze Process) are very effective in producing an all-around protective coating on magnesium alloys. Anodized metal can be dyed almost any color desired. Inasmuch as the coating is alkaline, it is not a satisfactory paint base unless after anodizing the parts are carefully processed to neutralize any free sodium ions and to give a slightly acid surface.

There is no limit to the number and types of paint, enamel, and lacquer finishes which adhere well to magnesium alloy. The black or grey crackle finishes are attractive and widely used. Plastic finishes in any color are possible using urea formaldehyde, phenol formaldehyde, or alkyd resin compositions.

Fig. 6—In these two views of an oxygen bottle A *shown wrinkling because of insufficient pressure on the pressure pad;* B *shows tearing of the metal due to too much pressure on the pad.*

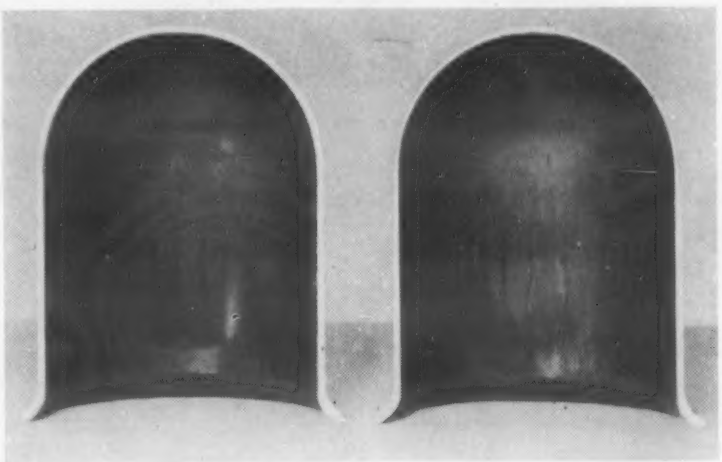


Fig. 7—Wall thickness is uniform in A *through use of a cooled punch, while* B *shows thinning of the wall from using a hot punch.*

Radiography with Multimillion-Volt X-Rays

by H. R. CLAUSER, *Associate Editor, MATERIALS & METHODS*

THE MOST SIGNIFICANT ACCOMPLISHMENT in the field of radiography during the war years has been the development of X-ray equipment to produce X-rays with energies above one million volts. This development not only makes possible improvement of established applications of radiography for materials inspection, but is also creating entirely new uses and introducing many additional possibilities for radiography.

This article is intended to survey the developments made in multimillion-volt radiography during approximately the past five years.

Multimillion-volt X-rays in this article refer to the X-rays generated by electrons striking the X-ray producing target with energies above one million electron volts. There are, at present, several different methods by which these high energy X-rays are produced. One method uses the electromagnetic generating principle for accelerating electrons and incorporates low frequency resonance transformer apparatus of a design similar to that used for producing one million volt X-rays. This method is limited to the production of X-rays up to two million volts. Another method, employing the electrostatic generator principle, developed by Van de Graaff of the Massachusetts Institute of Technology, is also capable of producing two million volt X-rays. A third method of producing high energy X-rays—and the most promising one—is by the acceleration of electrons by means of magnetic induction. This method has made possible the production of X-rays with energies up to 100 million electron volts.

The Induction Electron Accelerator

The first attempts to use the magnetic induction principle for producing high voltage X-rays were made in the 1920's by Wideroe[1], by Walton[2] and later by Steenbeck[3]. In 1940 D. W. Kerst[4, 5] completed the first successful electron accelerator at the University of Illinois; it produced an X-ray beam of 2.3 million electron volts. He named this instrument the "Betatron." Dr. Kerst secured a leave of absence to work with the General Electric Co. on the development of a 20-million volt betatron. Upon successful completion of this larger accelerator it was taken to the University of Illinois and Dr. Kerst returned there to continue his investigations and to supervise the construction of additional betatrons by the Allis-Chalmers Mfg. Co. Subsequent to the development of the 20-million volt betatron a 100-million volt electron accelerator was constructed by General Electric Co. under the direction of W. F. Westendorp and E. E. Charlton[6].

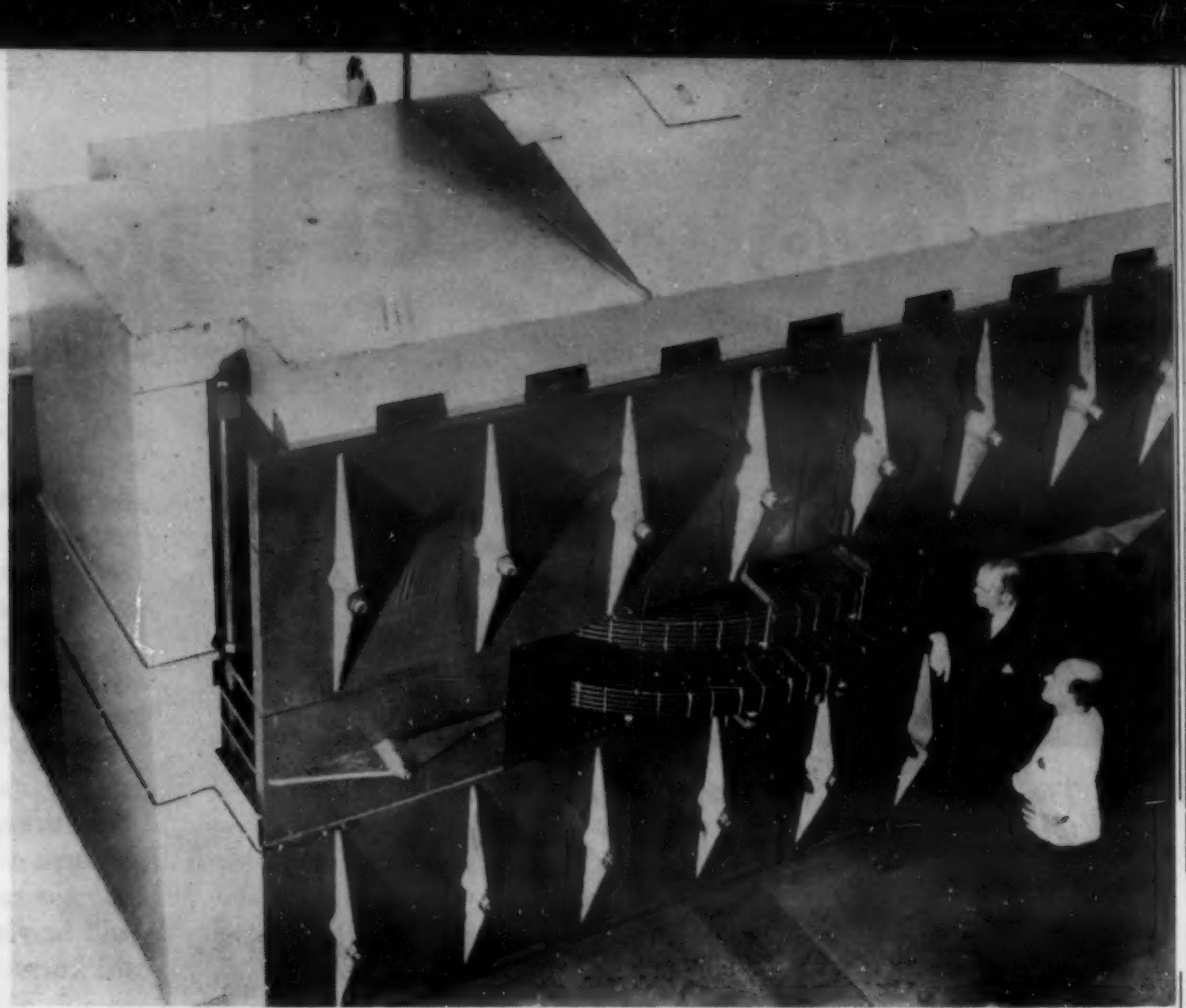
Recent high energy X-ray developments make possible better examination of materials and metal parts of complicated form and of greater thickness.

The equipment consists of two major parts—an electromagnet and the doughnut-shaped vacuum tube. The vacuum tube is located between the circular pole faces of the electromagnet.

To produce X-rays in the induction electron accelerator, or betatron, electrons are shot into a circular, doughnut-shaped vacuum tube and are caused, by a magnetic field, to describe a circular path. The electrons are continually accelerated around this path in the vacuum tube until they have acquired the desired velocity, when their orbit is expanded by magnetic means and strikes an X-ray producing target.

The induction electron accelerators employ an exceedingly small focal spot usually no larger than 0.01 in. The intensity of the X-rays generated depends upon the characteristics of the equipment and the voltage at which it is operated. With the 100-million volt equipment the intensity at 100 million volts can be as high as 2600 roentgens per min. at one meter, but when operating at 20 million volts it drops to 180 roentgens. The intensity of the 20-million volt betatron is something in excess of 25 roentgens per min. at one meter.

The half value width of the X-ray beam produced in the induction electron accelerator equipment is 5 to 6 deg. at 20 million volts and only 2 deg. at 100 million volts. The half value width refers to the angle measured from the center of the beam to the point where the X-ray intensity decreases one-half. Thus, at 20 million volts the effective cone of radiation would be 10 to 12 deg. This means, for example, that at a working distance of 10 ft. from the focal spot to the film an area 22 in. sq. could be X-rayed with one exposure.



The two electromagnets, between which is located a doughnut-shaped X-ray tube, are located in the center of this 100-million-volt electron accelerator.

At the present time electron accelerators are in the engineering development stage and before they receive wide industrial application for metal inspection they will have to be made more mobile and developed to a point where they can be easily maintained and operated by industrial technicians.

Two-Million Volt X-ray Equipment

The 2-million volt X-ray equipment[7], produced by the General Electric Co., is designed on the same principle as their one-million volt industrial apparatus. A multisection X-ray tube fits inside a low-frequency resonance transformer; both of the elements are mounted in a steel tank containing freon gas as an insulating medium. The tube has 24 sections of molded borosilicate glass tubing joined to fernico rings and is vacuum sealed. The electrons are emitted by a heated filament at one end of the tube. The high voltage is provided by the resonance transformer which accelerates the electrons in stages of 83,500 v. until they have the desired energy. Then they strike a tungsten target producing X-rays.

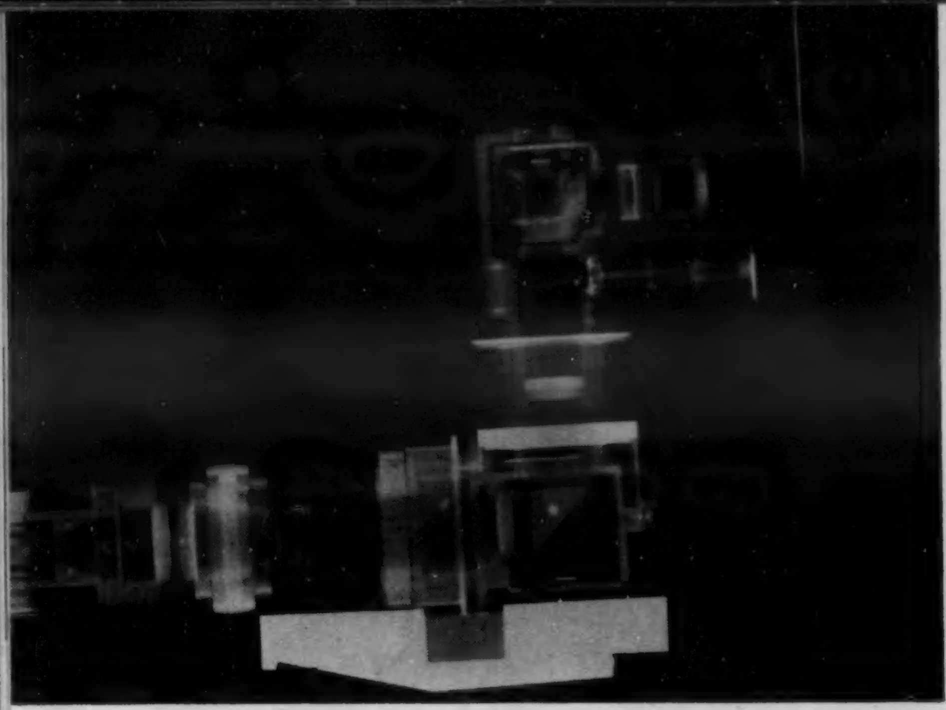
A magnetic focusing coil is utilized to control the focal spot size of the electron beam on the target. Without the magnetic focusing, the focal spot is about 0.8 in. in dia.; for industrial applications this is reduced as far as possible, usually to between 0.10 and 0.35 in. This cannot compare in size to the fine focal spot obtainable with electron accelerator and electrostatic generator type equipment. The 2-million volt unit is capable of X-ray intensities of around 200 roentgens per min. at one meter. The unit is 8 ft. long and 5 ft. in dia. and weighs 5000 lb. It is mounted so that it is mobile and can be positioned at any desired angle.

Another tube design capable of producing 2-million volt X-rays, developed by the Machlett Laboratories Inc., is operated with an electrostatic generator which produces the required potential[8]. The constant accelerating field over the length of the tube is provided by 180 sections which accelerate the electrons uniformly in stages of 12,000 v. The sealed off tube is 10 ft. long with a target of gold 1¼ in. in dia. and ¼ in. thick. The focal spot is maintained at a few thousandths of an in. by allowing the X-ray producing electrons to pass through a magnetic field lens which concentrates them to a fine spot on the target. The tube is employed with an electrostatic generator under several hundred pounds air pressure to provide the necessary insulating medium.

In electrostatic generators, of the Van de Graaf type[9, 10], electric charges from a generator are transmitted on a moving insulating belt to a metal high-voltage collector where the charges pile up; the potential thus accumulated is applied to one terminal of the X-ray tube. With electrostatic generator apparatus the focal spot size is comparable to that of induction electron accelerators being of the order of 0.01 in. The X-ray intensities may be as high as 60 roentgens per min. at one meter.

Penetrating Power of Supervoltage X-rays

The work that has already been conducted to investigate the ability of high energy X-rays to penetrate metal has revealed that the penetrating power through steel increases up to energy levels of around 10 million v. Above this voltage the rays begin to decrease in their ability to penetrate. Around 25 million v. the penetrating power again begins to increase very slowly until at about 50 million v. and above there seems to be no appreciable change. It should be noted that even though the penetrating power decreases above 10 million v. it is still advantageous to seek higher voltages from the length-of-



The increased clarity of multimillion-volt X-rays is shown in this radiograph of a German military periscope made with 2-million-volt X-rays.

exposure standpoint. As the voltage is increased the output of X-rays, or the intensity, increases thus making for shorter exposures.

There is some evidence that radiography of metal with X-rays above 40 million volts will not be practicable. Above this voltage undesirable tertiary rays are produced. These rays are even more penetrating than the primary beam, cause film fog, and thus tend to obliterate the true radiographic image.

With the tremendous increase in penetrating power it is possible to examine the interior of steel specimens as thick as 18 or 20 in. in a matter of minutes. One million volt equipment, formerly the highest voltage X-ray equipment produced for practical radiography, is limited to 7 in. of steel. With the 20-million volt betatron a 13 in. specimen can be X-rayed in 15 min. without the benefit of fluorescent screens. An automobile engine, in which there are some 7 in. sections can be radiographed in 2½ min. Using 2-million volt equipment of the resonance transformer type, it is possible to X-ray 12 in. sections with an exposure of 2 hr. and 8-in. thicknesses in 3½ min.

Improved Sensitivity with Supervoltage X-rays

One of the most important requirements of the radiographic process in the examination of materials is that it reveals clearly minute discontinuities. The measure of the ability of a radiograph to reveal accurately differences of density and thickness in the material being examined is termed sensitivity. Sensitivity is expressed as the ratio of the thickness of the smallest detectable defect visible on the radiograph to the thickness of the metal penetrated by the radiation, expressed in percentage.

Improved sensitivity is always being sought since the better the ability to reveal flaws the more valuable is this inspection tool. In ordinary radiography the sensitivity becomes poorer with increasing thickness, the best sensitivities achieved being around 1.0 to 2.0%. Besides this, a defect occurring in the material far from the recording film will not be recorded as clearly as the same size defect located very close to the film. For example, a radiograph having a sensitivity of 2.0% would reveal a defect 0.02-in. thick occurring in a 1-in. plate. Furthermore, the clarity of defect-image visible in the 1-in. plate radiograph would be much less if the defect occurred near the surface furtherest from the film than if it were located near the surface adjacent to the film.

In multimillion-volt radiography the characteristics of sensitivity are not the same as those for low-voltage X-rays described above. The phenomenon of "absolute" sensitivity is approached. Absolute sensitivity means that the sensitivity is independent of the thickness being X-rayed. The sensitivity does not become worse with increasing thickness as in low-voltage radiography; that is, a given minute defect will be visible on a radiograph regardless of the total thickness involved. For example, a 1/32-in. defect in a 2-in. plate and a 16-in. plate will be revealed on a radiograph with the same clarity. Furthermore, the sharpness of the defect image on the radiograph is not affected by the distance of the defect from the recording film.

Absolute sensitivity, although not achieved entirely, is progressively approached with the use of X-rays produced with energies beginning above one million volts. The characteristics which make the approach of absolute sensitivity a practical possibility are the reduction of secondary radiation and the use of an extremely small focal spot. Each of these is taken up in detail below.

Reduction of Secondary Radiation—One of the most bothersome problems encountered in radiography is secondary radiation. Most of this undesirable radiation is produced when the primary beam, upon leaving the tube, strikes the material being X-rayed. The secondary radiations thus set up proceed in various directions and many strike the film at an angle different from that of the primary beam. The result is that the contrast of the radiograph is lowered and the images of defects may be fuzzy instead of sharp and well defined. On radiographs produced with low-voltage X-rays a very large part of the film density is a result of secondary radiation. This "secondary density" makes up as high as 60 to 80% of the total density.

In multimillion-volt radiography the problem of secondary radiation is practically eliminated. One of the characteristics of these high energy X-rays is that the amount of secondary radiation decreases with increasing voltage. Through 4 in. of steel only about 15% of the film density is due to secondary radiation when radiographed with 20-million v. X-rays, and around 40% with 10 million v. X-rays.

Another form of secondary radiation, known as back-scatter, coming from the walls or other objects in the vicinity of the specimen being X-rayed, also reduces the quality of the radiograph. In low voltage work where there are large amounts of back-scatter,

lead shielding, sometimes as thick as ¼ in., must be placed back of the film. With high energy X-rays no such lead-backing is required because the back-scatter is negligible. Furthermore, when irregular objects are X-rayed, no lead blocking around the outlines is necessary as it is when lower voltage equipment is used. By the elimination of shielding and blocking the set-up time for X-raying intricate metal shapes is greatly reduced and irregular forms which could not be X-rayed practically because of the blocking or shielding required can be radiographed successfully with multimillion-volt X-rays.

Definition—The sharpness, or definition of detail, of images on radiographs depends to a large extent on the focal spot size. The finer the spot from which the X-rays emanate the more distinct on the radiograph will be the flaws revealed. The focal spot in electron accelerator equipment is a minute point, generally no larger than 0.01 in. In low-voltage equipment focal spots as large as 0.03 to 0.40 in. are used.

Because of the tiny focal spot (in addition to the negligible secondary radiation) the images of flaws distant from the film—as is often the case in thick-section radiography—are recorded clearly. Furthermore, it is possible to back the film away from the specimen without any loss of definition of detail. This is a desirable advantage when a magnified picture is desired to make easier the examination of details revealed by the radiograph. Also, in the X-ray of intricate shapes it is often not possible to place the film tightly against the back surface of the object. With low-voltage X-rays the resulting radiographs would appear fogged and indistinct; with high energy X-rays the quality of the radiograph would not be affected.

One other characteristic of multimillion-volt radiography should be mentioned; that is, the increased latitude it makes possible. Latitude refers to the range of thickness of material over which a radiograph can be taken resulting in film densities which are satisfactory for diagnosis. With low-voltage X-rays a variation of thickness over the area radiographed in the order of 10 to 20% is generally possible; with high energy X-rays the thickness variation can be as high as 100 to 200%, depending on the voltage, and the detail will still be recorded on the radiograph for satisfactory interpretation. Because of this increased latitude, objects having large changes in thickness or density over the areas to be radiographed need only be X-rayed once.

Applications

After learning the various characteristics of high energy X-rays it is easy to see the many applications this new development in radiography will have in the metal industries. In the foundry it will expand the use of radiography in the development of casting techniques and procedures for section thicknesses above 7 in. Not only will the increased penetrating power of these X-rays be used to advantage, but also their ability to reveal flaws in sections of great thickness variation and in intricate shapes which cannot be X-rayed practically with low-voltage X-rays.

Perhaps the most promising application is in the examination of mechanisms. Its good sensitivity, great penetrating power, as well as the feature of being able to place the recording film far back of the radiographed object, makes practical the examination of finished assemblies such as automobile engines, electric motors, generators, and complicated machinery. This application can be utilized in design work to investigate the motion of moving parts and to get strain measurements on assembled mechanisms. In addition, complicated assemblies can be studied during the various stages of fabrication and when completed to detect any flaws.

The introduction of multimillion-volt X-rays should also extend the use of stereoscopy, or three-dimensional radiography. By using stereoscopy accurate thickness measurements on inaccessible metal forms is possible. Exact locations of flaws in very heavy metal parts can also be accomplished by this means. And, again, for design work, three dimensional studies of the internal parts of mechanisms are made feasible and will be of invaluable assistance to designers.

These and many more applications will present themselves as radiography with multimillion-volt X-rays is further developed and continued improvements are made in electron accelerating equipment.

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High Temperature Furnace for Distilling and Refining Metals

by FRANK F. POLAND, *Revere Copper and Brass Inc.*

IT WAS RECOGNIZED early that nickel would become a critical metal in the war effort and therefore all nickel stocks and alloys containing relatively high percentages of nickel were frozen immediately. Among these alloys were considerable quantities of various grades of nickel silver, an alloy containing zinc, copper, nickel, and in some grades lead with minor amounts of iron, manganese, and other constituents.

At the time there was no existing plant or process to eliminate the zinc and other constitutents so as to convert this metal to cupro-nickel, one of the important alloys used by the U. S. Navy for condenser parts. The problem in converting these alloys to cupro-nickel was the elimination of the zinc, lead, iron, manganese, and other elements without appreciable loss of the nickel to slags or other by-products.

Revere Copper and Brass Inc. through its research and development department undertook to solve this problem and its efforts resulted in the building of a plant which successfully made the conversion.

The Process

Briefly, the process for making the conversion consists in distilling the bulk of the zinc from the copper and nickel, condensing the zinc vapor to liquid and casting into commercial metallic slab zinc. In the distillation furnace the metal is heated to a temperature of approximately 3200 F at which temperature the residual zinc in the copper-nickel alloys is approximately 3%. This metal is then transferred to a scorifying furnace which is a tilting reverberatory furnace equipped with several converter tuyeres. In the scorifying operation the zinc, iron, manganese, silicon, and lead are removed to the extent that the final product meets the U. S. Navy specification for 70-30 cupro-nickel condenser tubes.

Developed to recover cupro-nickel from nickel silver, this furnace can be used to melt scrap of many nonferrous materials.

Among the many features in connection with this project was the development of a resistor type electric furnace to operate at a uniformly distributed high temperature. This furnace is essentially an internally electrically heated retort and operates in the atmosphere of zinc vapor generated by the distillation temperature.

It will be realized from the following description of the furnace that the basic design is applicable to many other metallurgical processes in which it is of advantage to have a sealed furnace or to operate in a definite or controlled atmosphere.

Among some of the suggested uses are the melting of scrap aluminum, magnesium, copper, brass, ferro silicon, galvanizers zinc dross, and the silver-zinc skims from the Parke's lead refining process.

Shown in Fig. 1 is a side view of a dual unit and a zinc condenser built for condensing zinc distilled from nickel silver for the purpose of converting it to cupro-nickel. This unit has also been used for converting refinery grade scrap brass, fired cartridge cases, and brass turnings to metallic zinc slabs and fire refined copper ingots. The metal is melted in the first unit and overflows through a graphite tube to the high temperature distillation unit. In the melt-down unit there is maintained a pool of liquid metal and at the overflow end there is a liquid metal seal to prevent the zinc vapors escaping from the distillation unit to the melt-down unit.

In operation, the metal to be treated is charged into

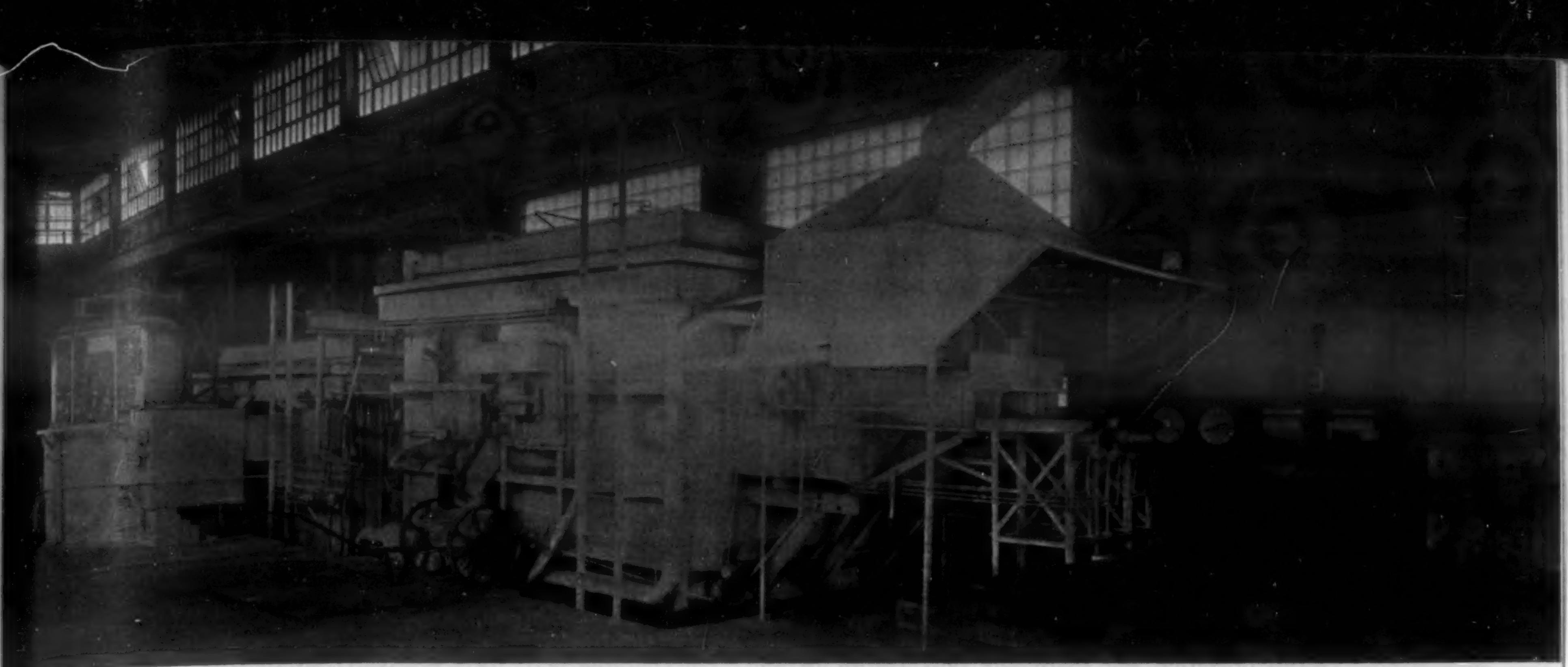


Fig. 1—This dual unit is used to melt and condense zinc distilled from nickel silver in converting it to cupro-nickel.

a vestibule in which is maintained an atmosphere of nitrogen, the nitrogen serving to prevent air from entering the furnace and to flush air from the interstices of the baled or loose metal.

Fig. 2 shows the charging end of the furnace and the control panels. The furnace illustrated is charged by hand. However, the charging can be mechanized and within reason the charging doors can be varied in size to suit the material to be melted.

The photographs show furnaces having a capacity of approximately ten tons per furnace charge. However, they can be built in larger or smaller sizes.

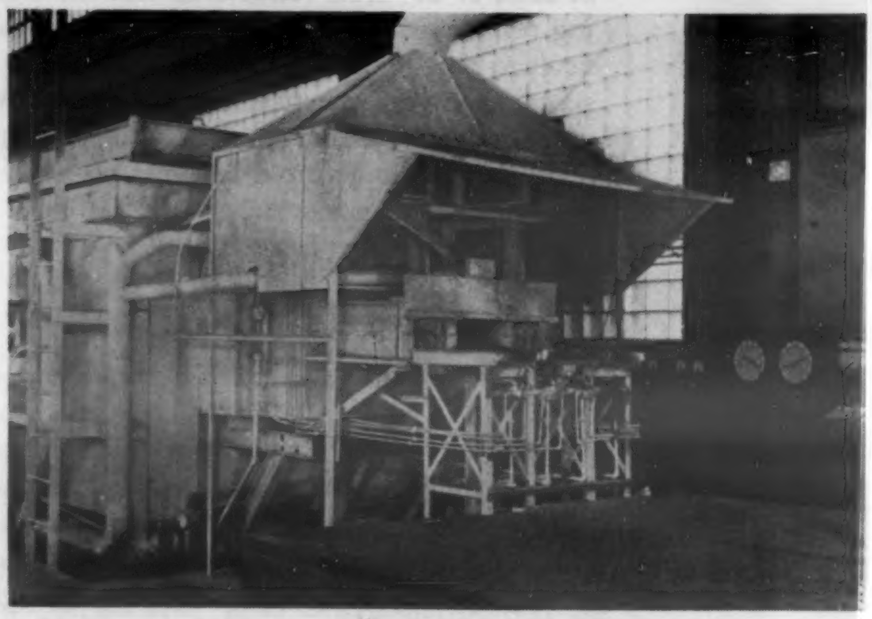


Fig. 2—Here are shown the charging end of the furnace and the electrical control panel.

Furnace Construction

These furnaces consist of a welded gas-tight steel tank lined with suitable refractories and with a one-piece removable roof. The joint between the roof and hearth section of the furnace is sealed with dual sand and oil seals. The melt-down furnace is provided with a sealed skimming door to remove any slag or dross that may accumulate on the surface of the liquid pool, and the distillation unit is equipped with a suitable tapping arrangement and has an outlet connected with a surface condenser used when distilling zinc.

The furnace hearth, sidewall and roof are of heavy carbon blocks backed up with fire clay brick and finally with insulation. The combination is so portioned as to maintain the outside steel shell at relatively low temperature so that the radiation loss is at a minimum.

The combination of high temperature metallic vapors and the need for a perfectly sealed furnace presented many refractory problems. However, they are all solved and some of the units have been in use for a period of two years with relatively low maintenance expense.

In the selection of the refractories particular attention was paid to the coefficient of expansion as

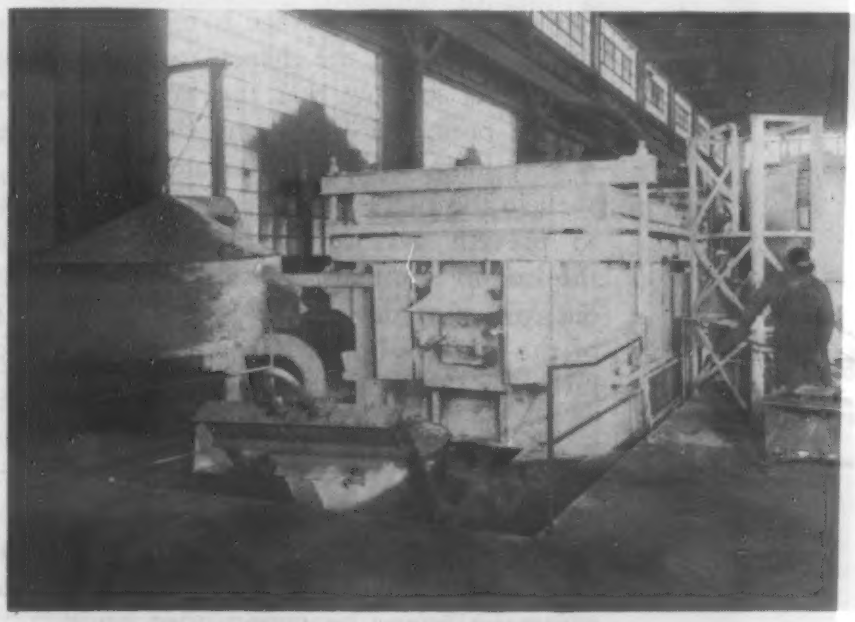


Fig. 3—Tapping and casting zinc slabs. Approximately 90% of the zinc in nickel silver and scrap brass is recovered.

the furnace is built into an air tight steel tank with no provision for expansion other than the compressibility of the insulating refractories.

The roof has a novel feature in that it is provided with a graphite plank roof to support the resistors and to radiate the heat from that part of the resistor that does not radiate directly to the hearth or side walls. Between the plank roof and the removable arched roof there is interposed a layer of charcoal as high temperature insulation so that the removable arched roof is kept at a minimum size and weight.

There are many minor features of the construction that are of considerable importance to its successful operation but space will only permit of an illustration such as the tap-hole which cannot be plugged with any of the usual clay mixtures because the temperature is very near or above the fusion point of most of the usual refractories and the higher melting refractories fuse to a hard dense mass that is difficult to tap. This was satisfactorily met by use of a simple but very practical tapping arrangement, the parts of which are made of graphite and are used a number of times before it becomes necessary to make replacements. Replacements can be made without shutting down the furnace.

Electrical Features

The furnace is heated with a graphite resistor element which consists of a built-up grid made from graphite electrodes. In the particular furnace being described the resistor consists of eight T-shaped elements, each approximately 5-ft. long, connected in series in such a manner as to have low inductance. This graphite resistor is connected through sealed in lead-in terminals to a 750 kva. single-phase, 60 cycle transformer. The transformer voltage can be varied from 55 to 85 v. in five-volt steps. Although a single phase resistor is used in the furnace being described it is feasible to construct a 3-phase resistor. Although variable voltage is provided for regulating the power input, the change in the resistivity of the resistor is so slow that the input remains constant over a period of weeks and the life of the resistor is very long. Copper plates are inserted in the steel shell in the area around the lead-in terminals in order to prevent overheating by induced currents from the lead-in terminals. The overall power factor without correcting devices is 85%. The energy efficiency of the Wilkins-Poland furnace is high and compares favorably with induction type furnaces.

Control

The heat capacity of these units in relation to the heat input is such that the temperature changes are gradual and it is unnecessary to have, for most uses, automatic power or temperature control.

Temperatures are indicated by means of radiation pyrometers, the target blocks being inserted and sealed in the roofs of the furnaces. The control panel at the furnace is equipped with temperature indicators and recorders for the roof temperature of each furnace and the condenser temperature. An all-on all-off remote power control relay is also on this panel.

In use for the specific purpose of distilling zinc from scrap brass and copper-nickel alloys, there are two furnaces connected in series. The first is the melt-down furnace that carries a liquid pool of approximately 10,000 lb. into which the cold material is charged. Any foreign material, slag or dross is allowed to float to the surface and is removed by skimming through a side door. At the end opposite the charging ports there is a teapot overflow through which the metal runs in a relatively continuous stream to the distillation unit. This unit is kept at or near the optimum distillation temperature so that the zinc vapor is produced at a uniform rate to simplify and maintain uniform condenser operations.

After the initial run in such an operation there are practically no non-condensible gases delivered to the condenser and it is regular practice to seal the condenser. That is, there is no vent on the condenser for the discharge of non-condensible gases. In the distillation of scrap brass and nickel silver alloys, containing lead, about 45 to 50% of the lead present is also vaporized and carried along with the zinc so that leady zinc is produced.

The zinc produced from refinery grade of scrap brass runs between intermediate and prime western in grade, the grade of course depending entirely upon the amount of leady brass on the charge.

The arrangement for tapping and casting zinc slabs is shown in Fig. 3. In treating nickel silver and scrap brass between 85 and 92% of the zinc present, depending on the zinc content of the brass, is recovered as slab zinc.

Other metals carried over with the zinc vapor are in proportion to their partial vapor pressure at the operating temperatures. The melt-down furnace, of the unit being described, is operated with the minimum degree of superheat to avoid distilling the zinc as no provision is made to withdraw vapor from this furnace other than what would discharge or condense into the charging ports.

The distilling or high temperature furnace can be arranged so that molten metal from any source or from some other type of melting furnace could be charged, and other types of melting furnace may be preferable for the melting of specific materials. Such a case would be one in which a large quantity of foreign material would have to be skimmed from the molten metal or one in which melting under a controlled atmosphere would be unnecessary.

There has been an unusual amount of interest shown in these furnaces and in the process by domestic and foreign companies in the nonferrous metal industry, and there will undoubtedly be other plants built in the immediate postwar period.

Welding stainless steel is not particularly difficult, but those attempting to do so must take into consideration differences between it and mild steel.

Welding Stainless Steel . . Part I

by C. C. HERMANN

WHEN THE ENGINEER is faced with the problem of selecting a material which will not corrode, he thinks of "stainless steel." After a brief investigation, he determines that his material cost alone will be nine times that of ordinary steel and he hesitates. Then he discovers that fabrication costs for stainless steel range from two to three times that of steel and he throws up his hands in despair. He is now in a frame of mind which makes him an easy convert to iron or steel construction with corrosion resistant coating.

The engineer is, to an extent, justified in his course of action, however, if he carries his investigation into the realm of maintenance cost during the life of the structure and later replacement cost he finds the pot of gold at the end of the rainbow. A corrosion resistant coating on iron or steel is a slight thread indeed to support a reputation. The smallest pin hole in the coating unnoticed by the inspector will prove disastrous and in the end the cost outlay is made for a stainless steel replacement.

The most popular stainless is the 18:8 group of which there are many trade brands. Type Nos. 302, 305, and 307 are more commonly used but when the carbon content must be limited to 0.08% max. type Nos. 304 and 306 are specified. There is a small increase in price for the lower carbon types.

A second group of stainless is likewise popular for some vessels; namely, 25-12 such as Enduro, NCN, Uniloy Special 2411, U.S.S. 2512, Rezistal 3, Midvaloy 25-10, Empire 24-12, and many others.

The 18:8 steels are soft and tough as-welded, are non-magnetic, harden when cold worked but cannot be hardened by any form of heat treatment. To resist corrosion best the steel is heated to 2000 F and quenched, which anneals it. The straight chromium types are usually brittle as welded, they do not anneal, and are magnetic, thus they are difficult to handle.

When selecting a stainless for a given corrosive condition, it is well to bear in mind that the laboratory conditions under which the steel is tested are difficult of duplication in practical application. In the process and chemical industries are found all manner and mixtures of gases and acids. Some corrosive acid may be present as only a trace or very small percent but in combination with the bulk of well-known substances the combined effect on the steel can be disastrous. The first step, therefore, in the choice of material is to determine, beyond the shadow of a doubt, just what the corrosive condition is and design accordingly.

Temperature at which the vessel must prove resistant is important. The 18:8 alloy is most resistant to corrosion in the annealed condition so long as the temperature of the liquid is low. For high liquid or gas temperature such as encountered in chemical plants the 25:12 type stainless should be used.

The annealing of 18:8 vessels after welding is important but oftentimes difficult, due to size, structure and accuracy required in the finished work.

Titanium Adds to Accuracy

For accuracy in the finished work, a stainless having a small percent of titanium should be used. Much could be said regarding the effect of heat treatment or lack of same on stainless steel, however, this lies in the field of the metallurgist and must be passed herein. Suffice to state that heating 18:8 to 1850 to 2100 F and rapidly cooling by quenching reduces intergranular corrosion and annealing at 800 to 1400 F precipitates the carbides again so that from a practical point of view it is most logical to select a welding electrode having slightly less carbon

content (0.05 to 0.07%) and some titanium such as type 320-321 in all cases.

The foregoing very brief discussion of the simpler characteristics of 18:8 and 25:12 stainless should suffice to lead the designer to a more careful selection of material as to type. The lowest price material consistent with results will be the answer.

Too many designers go off the deep end when it comes to weight of stainless to employ. The design should be along the lines of mechanical strength by reinforcing with lower price materials, consistent of course, with useful life of the vessel as a whole. Thickness of the stainless steel affects directly, in many instances, the life of the structure. Laboratory tests show the expected decrease in thickness in a time element when subjected to a given corrosive acid and the designer should acquaint himself with these factors. In actual practice, however, it is usually the case that where corrosion is present it goes through the sheet with such rapidity that extra thickness as an economical factor is uncertain. It is far better to work on the basis that the steel is either totally resistant to the acid or unsuitable. If unsuitable, then select an analysis or type of material which is resistant.

On the latter basis the design may proceed along the lines of mechanical strength obtained by banding, ribbing, or reinforcing with common steel of lower price per pound. In this manner the minimum weight of the higher price stainless will be used and providing the differential is not entirely absorbed by use of additional man hours of labor in the fabrication, a minimum first cost is procured.

Undoubtedly the semi-stainless type of fabrication of such vessels will advance in future construction. Stainless clad steels are a partial answer. Stainless clad steel is a two-or-more-ply steel having 15 or 20% thickness of stainless steel laid on a foundation of soft or mild steel. This sheet was developed to provide the corrosion-resisting advantages of stainless at a reduced cost. Its use is broadening having been used heretofore in construction of vessels for resistance against the milder corrosive agents such as salt. The design of this steel is on the basis that the very thin stainless is either wholly resistant to the substance encountered or it should not be used. Some of the objections to its use are mold steel edge and the same exposure to cope with in connection with openings in the vessel.

Many fabricators object to working on stainless clad sheets and composite designs such as stainless sheets reinforced by mild steel. This is justified on the basis that cutting tools, punches, and shears are provided with suitable clearance and shear to handle stainless but would be not entirely suitable for mild steel. Also welders become adept on stainless but confused when changing from stainless to mild or visa versa. Although there is considerable difference in the technique of welding stainless as compared to mild steel, yet it would seem just as advisable for a welder to be qualified in both types as for a trombone player to be able to play a flute. Without discrediting specialization it is quite apparent that fabricators will handle more and more composite structures in the future. More will be said on this subject later in connection with fabrication methods.

Wrong Stainless Increases Cost

The designer can increase his labor cost by specifying the wrong type of stainless, the wrong thickness of material and the wrong class of weld. If he is familiar with shop practice regarding lay-out, cutting, stock sizes of sheets, fabrication and welding of stainless then he can go the limit in his specifications. On the other hand, if he is not entirely conversant with these procedures it would be best that he write a flexible specification and let the experienced fabricator use a free hand to produce the desired structure. Specifications closely written more often protect the fabricator than the purchaser in that those developed by an inexperienced person offer all the loopholes necessary for the fabricator to work out of any situation. About the simplest and air tight specifications I ever read stated the case in the following terms: "The contractor shall furnish a tank of the type and having the dimensions shown on the drawings, made of 18:8 stainless steel, electric welded throughout, and to be capable of withstanding a pressure of 100 millimeters of mercury continuously." Not an all-inclusive or elaborate specification but exacting enough that there were no loopholes for the fabricator to slap on a number of extras. Needless to state, the job was purchased at a minimum cost because competitive bidding took into account plant efficiency and overhead charges as well as fabricator profits. Each bidder was able to use his own developed methods rather than be bound by methods with which he may not have been familiar.

A vast book could be written on the subject of welding stainless steel fully 80% of which would have no meaning to 95% of the plants in the business. In the following paragraphs are described only those practices which are more or less standard in all shops.

What welding characteristics of stainless steel differ from those of mild steel? They are three, namely—electrical resistance, thermal conductivity, and thermal expansion.

The electrical resistance of 18:8 stainless steel is 6.4 times that of low carbon steel. What does this mean to the welder? In plain understandable terms it means that whereas he can use an electrode 6 in. long between the holder and the work when welding mild steel he must cut this to less than 1 in. with stainless electrode for the same generator setting. What does he do? For butt welding 14-gage 18:8

stainless steel he would set his instrument panel for 60 amp. at 24 v. using a 3/32-in. electrode. For mild steel the corresponding settings would be 120 amp. at 23 v. using ⅛-in. electrode. Obviously he would not shorten the length of his electrode in the ratio of one to six but would adjust his current setting to overcome the extra high resistance of the stainless electrode. At the same time the electrode length would be such as will not result in overheating. Stainless steel electrodes should, of course, be heavily coated.

The thermal conductivity of stainless steel is about one-third that of mild steel; therefore, the chances of overheating the work as well as the electrode are present. This is why a lower amperage setting is used and explains why there is always some discoloration of the work on either side of the weld. A surface oxide forms due to high heat or retention of heat but the color can be removed by pickling, or grinding and polishing. The latter method is generally used.

The third important characteristic is thermal expansion which is about 1½ times that of mild steel. Mild or low carbon steel practice applied to stainless steel would ruin the work entirely due to this factor. Considerable buckling and warping results. The welder must so adjust his heat and method of applying metal to avoid this fault. He will lay down successive layers of metal rather than try to form a complete heavy bead at one pass. Thus he allows time for the heat to dissipate before applying more heat.

In these three factors is found the cause for the relative high cost of welding labor as compared with mild or low carbon steel. Many studies reveal that a good experienced welder will produce about one half the weld in ft. per hr. on stainless steel than he would on low carbon steel.

Common Welding Positions Used

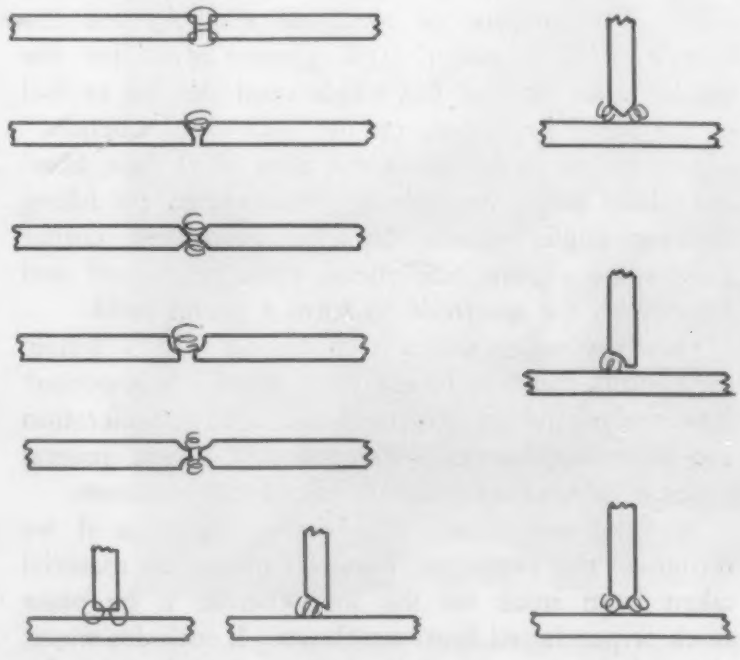
The usual welding positions are commonly used for stainless steel namely—down-hand, vertical, and overhead. The polarity used is electrode positive, work negative. The type of joints are butt, lap, and fillet. It is up to the designer to determine the type of joint to be used. He will be governed by such considerations as: (1) Are tension or compression forces present? (2) Will the joint be subject to bending, fatigue or impact forces? (3) Is the load to be applied in a steady, variable or sudden manner? (4) Has a comparison on the basis of cost of preparation and welding been made and which is the more economical joint?

Butt joints may be square, single V-bevel, double V-bevel, U-single, U-double, square-T, bevel-T, double bevel-T, single-J, and double-J. These joints are shown in an accompanying illustration.

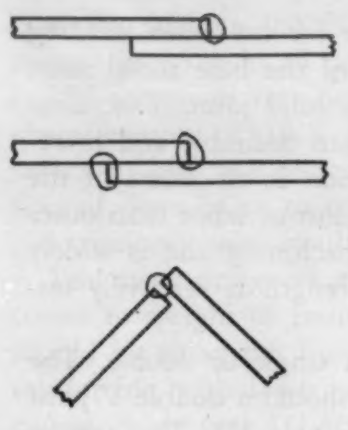
The square butt joint is suitable for light loading but is not a satisfactory joint for use when welding stainless steel because much of the base metal must be melted down to procure a solid joint. Discoloration will run back further than desirable and to remove it will result in reduction in thickness of the sheet. This joint is lower in cost of labor than other joints since there is no pre-machining and is widely used on thin stock where strength is relatively unimportant.

The V-joint is made either single or double. The question often arises: When should a double V-joint be used in preference to a single V? The answer is: When the stock thickness is such that the single V would prove unsound. The preparation of the joint is more costly than the single V but less expensive in regard to welding rod and welding labor because only about 50% as much rod is used to make the joint. The selection here is the cost of preparation compared with the welding cost. Either of these joints are suitable for usual load conditions either tension or compression.

The U- and J-joints are similar except that the U-joint applies to the joining of two members in the same plane while the J-joint applies to two members joining at right angles to each other. The U-joint is a high strength joint when accurately made and will be suitable for all usual loads. It is only practical on plates 3/18 in. or thicker and the double U-joint is used where the plate thickness is too great for the single. Compared with the V-joint the cost of machining will be higher but less electrode will be used. The same arguments can be advanced for the J-joint as compared with the single and double T-joints. The J-joint is used on heavy plates for severe loads. The double J-joint is used



These are the commonly used butt joints used in welding metals. All are applicable to stainless under proper circumstances.



Lap joints (upper left) are commonly used on stainless steel and are in the same class as the fillet welds used to fill angle corners.

These are two variations of V-welds, in the one a bottom plate is welded to the bottom side of the gap.

on heavy plates ¾ in. and up. It is considered good practice to lay a small bead on the back of the single J-joint.

The square T, single bevel T and double bevel T are popular joints. Of these joints the square T is the lowest in cost due to absence of machining and it is used on all thin plate work. The double T-joint requires more machining than the single T but uses less electrode and is a stronger joint. This joint is suitable for heavy loads in longitudinal or transverse shear.

Lap joints are common and can be single-lap or double-lap. No machining is required with either joint. The amount of electrode required for the double weld is about 60% greater than for the single, since one of the welds need not be as full as the other depending on the load requirements.

Lap joints really fall in the fillet weld class, however, fillet welds are generally considered for filling between angle corners. In a so-called flush corner joint some of the base metal must be melted and fused with the electrode to form a sound weld.

How are we to select from among the 15 widely used joints the type to use for a given construction? Any analysis of the job must take into consideration the following factors: Material cost, labor, general expense or overhead, useful life of the structure.

Material cost is not difficult to determine if we recognize the elements. Material means all material taken from stock for the job whether it be plant stock or purchased from warehouse. It includes waste, electrode, waste electrode, bolts, nuts, material for clamping or holding while welding, and, in some instances, it includes supporting steel. Where manufacture is not repetitive in nature it also includes sheets for patterns.

Proper Cutting Reduces Waste

Waste must be kept at the absolute minimum when fabricating stainless steel since the waste will show the same pound price as material actually going into the product. All too frequently, excessive waste results from fabrication of a single unit. The best way to control waste is to select sheet sizes and make actual developed layouts indicating to the cutting department just how the sheets are to be cut and just where the sheet ends are to apply. By wise study and proper lay-out the least waste will result. The old rule of the thumb as 10% waste or 12% waste, has no standing here. When the job is finished all waste should be weighed and together with the weight of the finished article compare with purchase weight.

With stainless steel, bevels are generally obtained by grinding or with some shaping tool. When grinding a bevel on the edge of the stock it is important that straight, even lines be maintained otherwise the joint will be uneven resulting in draw to a warp when welding. For this reason, machining might be found superior and more accurate.

Instead of planing the edge to a U- or J-shape welding a bead along the bottom of a V is sometimes used. In one case a simple V-edge is prepared and then a flat piece is welded to the bottom side of the gap. Shops specializing in work of the heavier type involving U- and J-joints will be supplied with forming tools to produce the desired shape. A mill with special formed cutter will be found to be about the lowest cost type of machining.

Preparation involves selection of stock for the job. It would be very foolish to store stainless steel promiscuously. However, many storage piles of stainless steel observed leads one to wonder if the employees do not consider the material as just so much steel instead of material which runs as high as fifty cents per lb. Stainless steel should be stored in its original shipping crate on edge with protective paper left between the sheets if polished stock. As a result of careless storage considerable bend and wrinkling of the sheets results and it is next to impossible to straighten out some of these faults. Obviously trouble will be experienced in fitting a pattern or making layout on a wrinkled or bent sheet and further trouble will be encountered in fitting such sheets together for welding. As mentioned in a previous paragraph stainless steel will discolor in the atmosphere and, although this discoloration in itself will not hinder welding, it will result in the accumulation of dirt and foreign matter which will interfere with the welding operation in that it will float to the surface of the weld resulting in additional slag. Of course all slag must be removed from the weld during the welding operation.

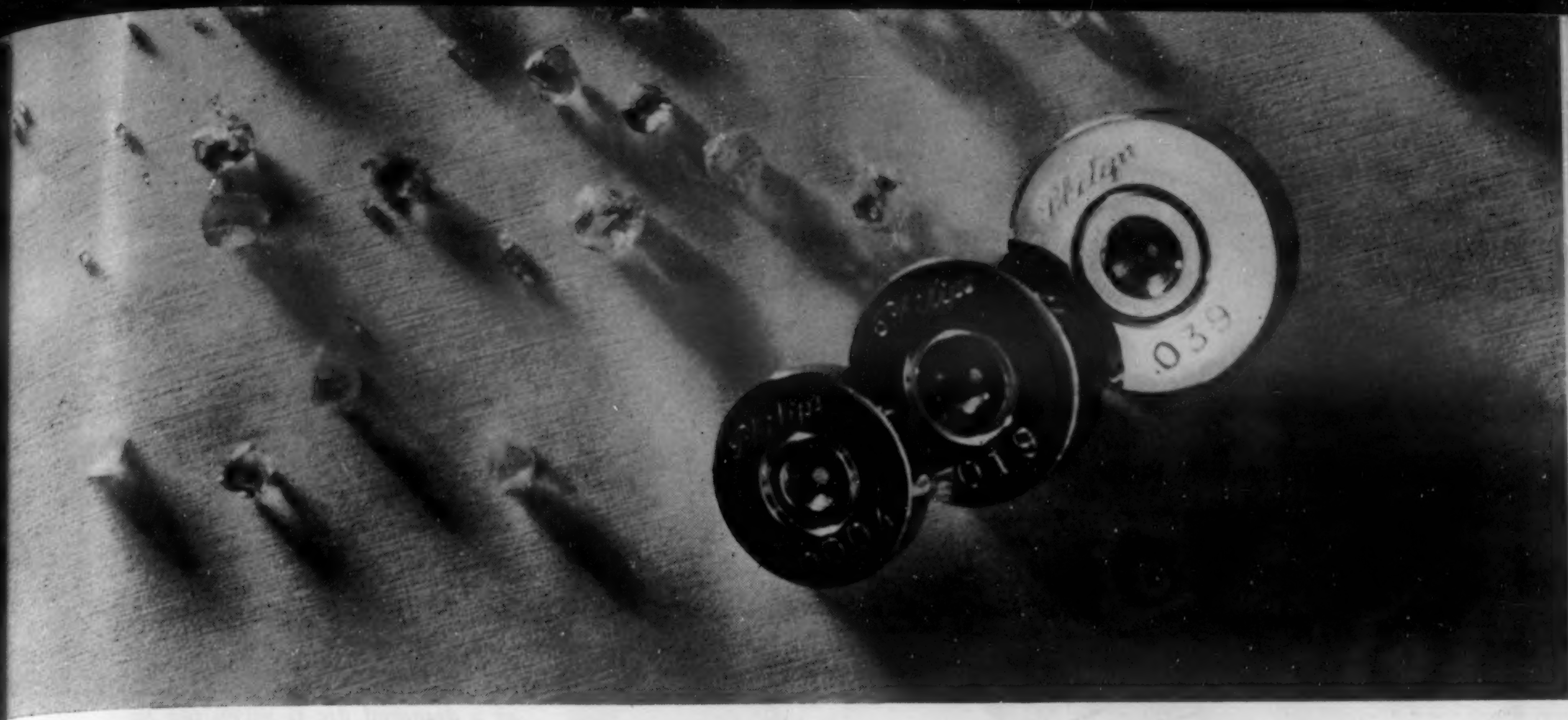


Fig. 1—A group of diamond wire drawing dies of varying sizes and undrilled diamonds which will be drilled to produce other dies. Precision requirements can be realized by studying the minute diamonds used.

Diamond Dies for Wire Drawing

by C. K. WALL, *North American Philips Co.*

Diamond dies, long a product of hand craftsmen, are now turned out in large quantities by high-speed precision methods.

ONE OF THE PRIME requirements of wire drawing dies is hardness and through the evolution of the die industry various materials with an increasing degree of hardness have been used. About 1000 years ago the monk Theophilus described a wire drawing die as: "Two pieces of iron, three or four fingers wide, smaller at the top and bottom, rather thin, pierced with three or four rows of holes through which wire may be drawn."

The first reference to drilling hard precious stones is made in a British patent issued in 1819. A half-century later diamonds were drilled to make fine wire drawing dies. The method of drilling diamonds has evolved from the slow hand process of the European home craftsmen to that used today in which high-speed precision tools are used.

Fig. 2—Using boart (diamond chips) the operator makes an indenture in the flattened surface of the stone to make a center point to guide the needle during drilling process.

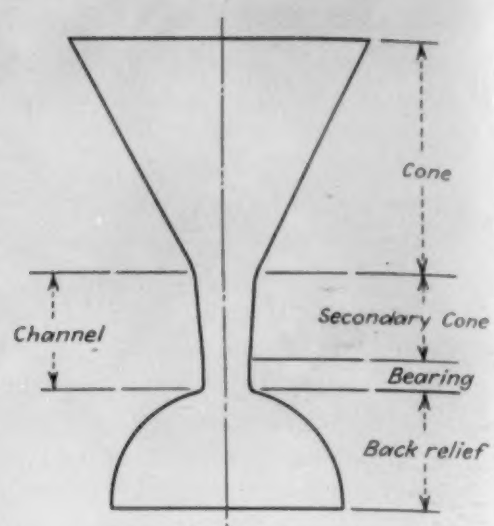


Fig. 3—In this schematic drawing of a diamond die is given the nomenclature of wire drawing dies.

Fig. 5—(below) Through a window ground perpendicular to parallel flats it is possible to observe the drilling process through a microscope. The actual drilling is achieved through a blunt needle using an abrasive of diamond dust suspended in oil.

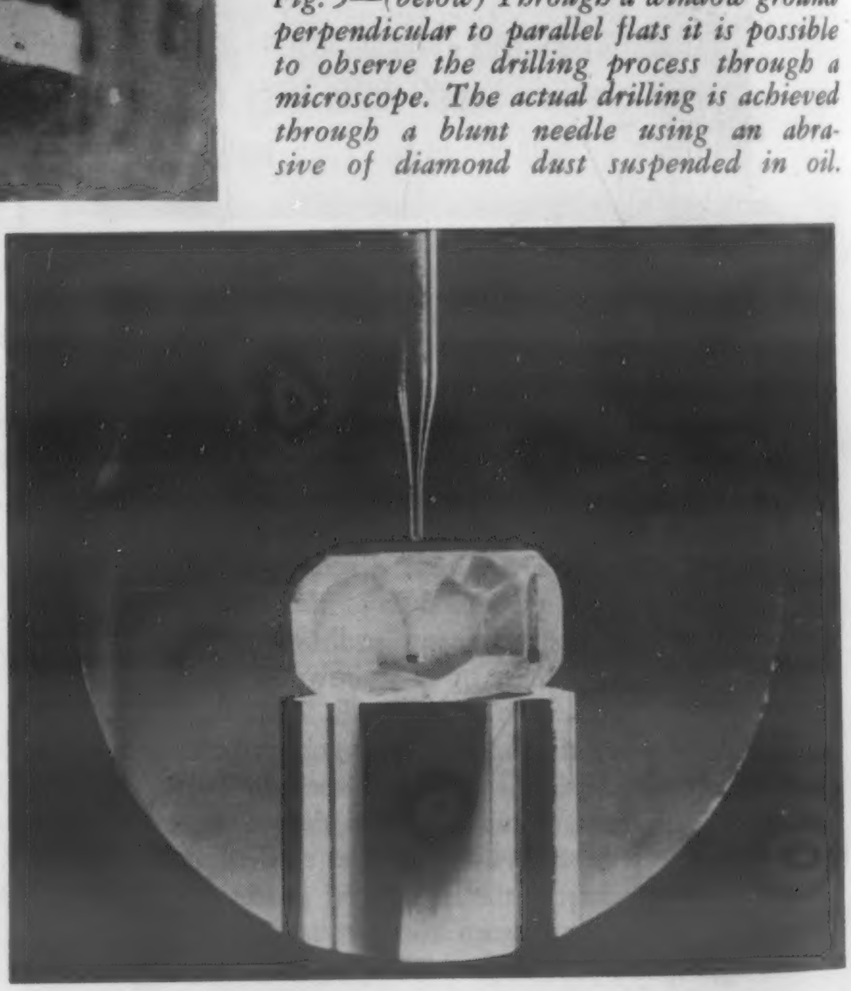


Fig. 4—To make the opening between cone and back relief, the diamond is mounted on a gently oscillating spindle and is observed under a microscope to prevent a breakthrough with consequent damage to the bearing surface. The needle is ground to a blunt round point and the operation continues until there is a clean countersunk exit between the bearing and the back relief.

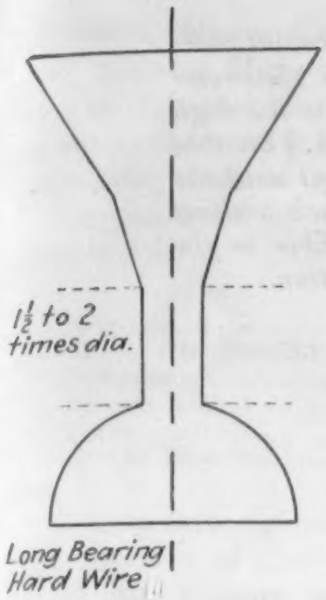


FIG. 6

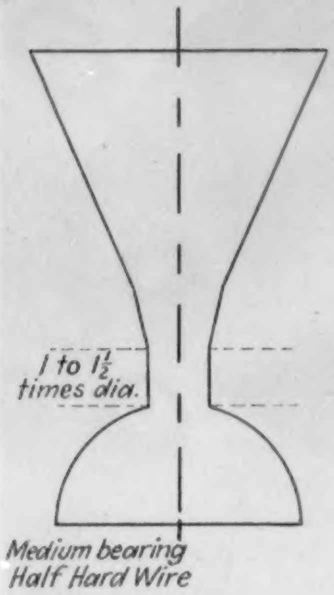


FIG. 7

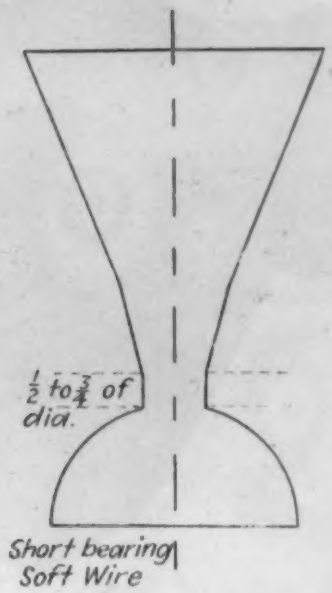


FIG. 8

Figs. 6, 7, 8—For hard wires, such as tungsten, molybdenum and nickel alloys, a long bearing die should be used. Slightly shorter, but still comparatively long is the bearing channel for half-hard wires such as phosphor bronze, steel and hard brass. Soft wire materials including copper, bronze, gold, silver, platinum, aluminum and soft brass require only a short channel.

Fig. 9—This is an example of a poor die. Rings apparent throughout the cone and channel result in rapid die wear. Lack of concentricity in the back relief will soon result in the die being out of round.

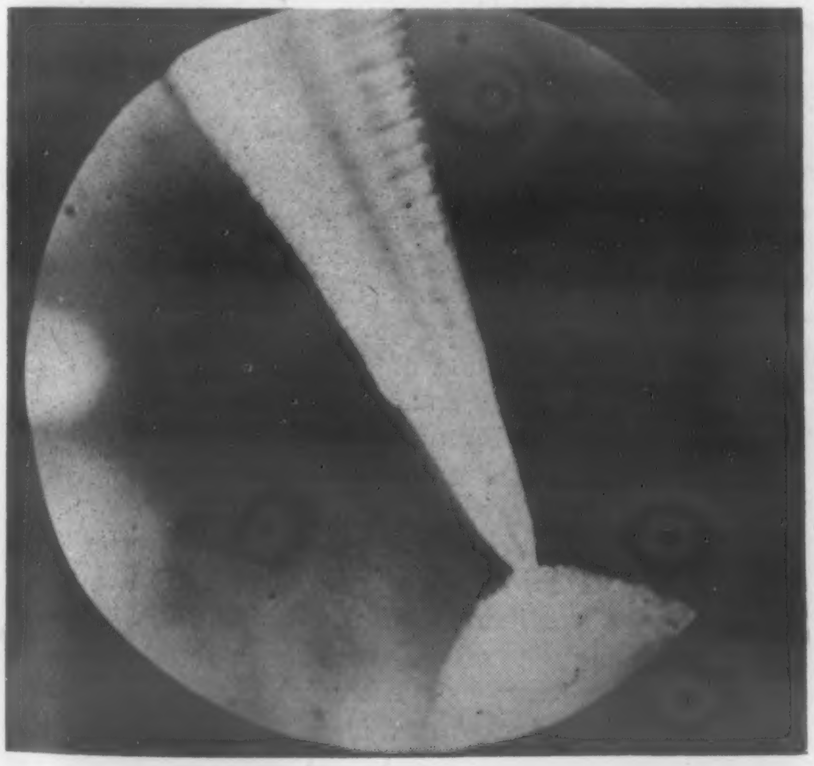


Fig. 10—Here is a well polished die in which a mirror finish is attained in the secondary cone and bearing. This feature keeps die wear to a minimum and results in maximum uniformity in the wire produced.

One of the important characteristics of glass-reinforced plastics is the high flexural strength. This thin sheet can be bent until the ends almost touch without damaging the fiber or the resin impregnation.

Properties and Fabrication of Glass Reinforced Plastics

by JAMES SLAYTER and H. W. COLLINS, *Owens-Corning Fiberglas Corp.*

This article is based on a paper presented by Mr. Slayter and Mr. Collins before the American Institute of Chemical Engineers.

Properties of glass-plastic materials indicate their use for many types of products where strength and stability are required and complex shapes are involved.

WHILE THE WAR WAS ON, all effort was concentrated upon developing glass-resin combinations to meet war requirements. Civilian use requirements are not necessarily the same as the requirements of war, so the cooperation of those responsible for the selection of materials and design of end-use products is essential to the full and rapid development of glass-plastics for civilian applications.

The high strength-weight ratio of individual glass fibers used for plastics reinforcement underlies the high strength-weight ratios of the finished laminates. Tensile strength of individual glass textile fibers, in the order of 300,000 psi., is compared with tensile strengths of other materials in accompanying charts.

High tensile strength of glass fibers, combined with

3% elastic deformation—the same deformation at break as cotton fiber—provides an energy absorbing value several times that of steel. The energy absorbing values of several materials are compared on an accompanying chart.

The properties of representative cast resins are given as follows:

Tension	9,000 psi.
Modulus of Elasticity	0.4 x 10^6 psi.
Compression	25,000 psi.
Flexure	25,000 psi.
Impact	0.5 ft. lb. per in. of notch
Specific Gravity	1.3

Keeping these figures in mind, note Table I covering properties of glass-plastic laminates made at 10 to 15 psi. pressure, with the glass reinforcement oriented to give equal strength in all directions. It is apparent that glass-plastic laminates provide a material possessing extraordinary strength in relation to weight. Other properties possessed by the material are no less important.

Table I

Reinforcement	Properties of Laminates					
Woven Glass Cloths	Tension psi.	Compression psi.	Flexure psi.	Ef psi.	Impact ft. lb. in. width	Specific Gravity
ECC-112	38,000	30,000	42,000	2.2 x 10^6	22	1.70
X-1699	42,000	33,000	55,000	2.5 x 10^6	23	1.85
ECC-128	37,000	17,000	33,000	2.2 x 10^6	20	1.80
ECC-164	31,000	13,000	26,000	1.8 x 10^6	27	1.70

Dimensional stability is one of these other properties. Natural fibers and all synthetic fibers made of organic substances absorb moisture to some degree. The absorption of moisture causes them to swell as they become wet, to shrink as they dry, and to lose strength. Swelling and shrinking inevitably affect the dimensional stability of the plastic products in which they are used as reinforcement.

Glass fibers, being inorganic, and being microscopically fine solid glass rods, absorb no moisture. The only moisture they will retain is that which can adhere to the fiber surfaces. The amount of moisture that can adhere to the fiber surfaces is relatively low and surface treatments recently developed replace and repel the adhered film of water.

Because glass fibers will not absorb moisture they will neither shrink nor swell under changes in moisture conditions. In addition, they possess a low coefficient of thermal expansion and are strong enough to resist normal expansion of the resin. The accuracy of dimensions of molded parts can be controlled with high precision because the material has a predictable and very low coefficient of thermal expansion.

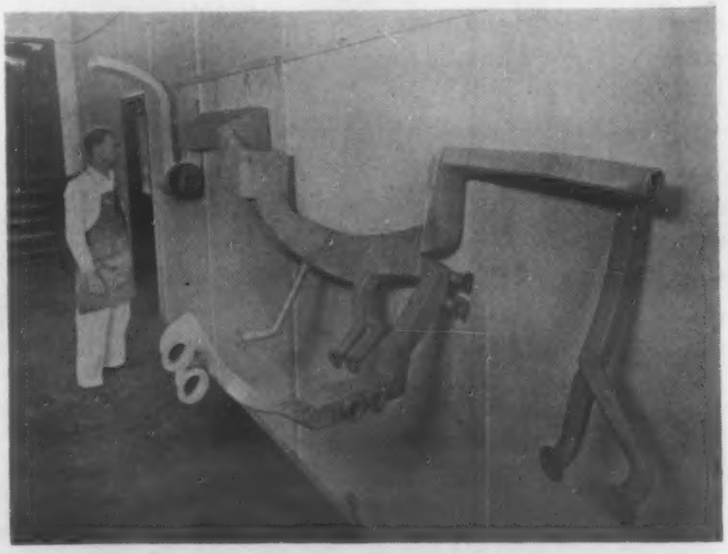
The ability to obtain directional properties is a great advantage in design. If stresses to which the product will be subjected will occur in several directions, it is possible to distribute the glass fibers in these directions in proportion to the amount of stress in each direction. If the principal stress is to some in one direction, it is possible, by arranging the glass fibers in the direction of stress, to exceed the strength of structural metals. In four accompanying charts on strength properties, values are based on laminates made with heat-treated, unidirectional glass cloth and a representative low-pressure resin molded at 15 psi. pressure. Specific strengths are original strengths divided by the specific gravities of the materials, except for specific flexural strength which is obtained by dividing by the specific gravity squared.

In metals the modulus of elasticity is not variable, but the modulus of glass-plastic products is controllable over a wide range. This control is a function of the amount of glass cloth used for reinforcement.

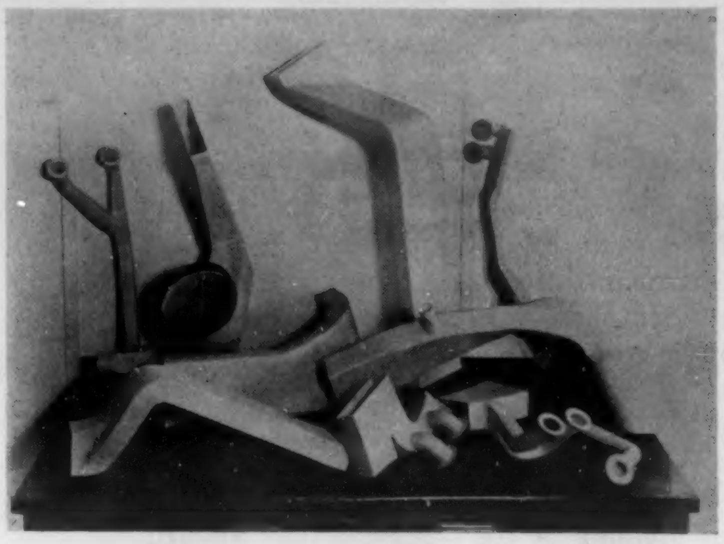
Glass-plastic laminates have good dielectric strength. They have no definite yield point, so it is possible to work the material very close to its ultimate strength without permanent deformation. The same characteristic prevents the material from denting when struck a sharp blow. Because of its fibrous structure and the consequent scattered distribution of any imperfections, the material will not propagate cracks.

Glass fibers will not rot, they retain their strength over a very wide range of temperatures and, because they are the end product of oxidation, they will exist indefinitely in an atmosphere of oxygen. Weathering resistance is largely a combination of these properties. Glass fibers contribute these properties in a higher degree than other reinforcements.

The wet strength of many materials is adversely affected by long exposure to moisture, but on the basis of experiments now being conducted it appears that by applying to the glass fibers a silicone in water



Glass-reinforced plastic hot air duct manufactured by Toyad Corp. of California for Hughes Aircraft Co. demonstrates use of this material for undercut, hollow and complex parts.



These are the individual parts which are joined to complete the hot air duct shown in the previous illustration.

solution, it will be possible to bring the wet-strength of glass-plastic laminates up to a point very nearly equal to their dry-strength. A series of silicone treated glass-plastic laminates retained over 90% of their initial strength after submersion in water for seven days.

Other series of test specimens have been immersed in solutions of various chemicals, including certain concentrations of both acids and alkalis, for periods up to seven days and at temperatures up to 200 F. Complete immersion of the specimens made the tests more severe than the conditions that would be encountered in using the material for pipes or tanks, for in such applications the material would be exposed to chemical attack on only one surface.

Test results indicate that glass-plastic laminates have sufficient chemical resistance to permit their use as underground oil pipes. Their resistance to electrolysis also indicates their suitability for cross-country underground pipe lines and similar installations.

In addition to carrying on research aimed at the development of new or improved glass reinforcements, experimentation is being conducted with low-density core materials for use in the construction of sandwich-type glass-plastic panels. The great advantage of such panels is that they can combine large area with rigidity, or resistance to buckling, and extremely light weight.

The panels can be formed in simple and compound curves as well as in flat sheets. They can be designed for either structural or decorative applications. They can be designed to provide excellent sound and heat insulating and vibration-dampening properties. The complete panels are easy to assemble and, because large parts can be made in one section, they eliminate much riveting and bolting.

Fabrication of Parts

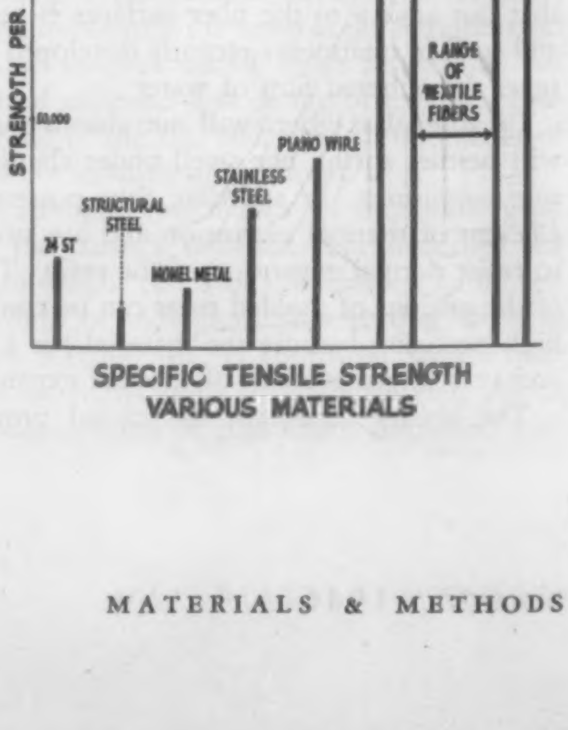
Because the low, or contact, pressure resins polymerize without giving off volatiles, it is possible to cure them in any desired shape merely by holding them in contact with the mold. This makes possible the fabrication of very large parts—the whole top of a railway car or the hull of a boat, for instance—without the expense and physical limitations imposed by the use of high-pressure presses.

It also means the elimination of expensive dies and jigs, for since high stresses are not applied to the molds they can be of inexpensive construction. All this adds up to the fact that low-pressure, glass-reinforced plastics can simplify and lower the cost of fabricating many parts, particularly large parts and those involving compound curves. They permit a frequency of design change that is uneconomic when there is a heavy investment in costly dies.

In general, their field appears to be the range and variety of parts that are produced in the hundreds or thousands rather than in the millions, and in the production of which, because of their relatively small volume, the cost of expensive metal dies is a prohibitive or burdensome factor.

Glass-plastic laminates can be given a highly polished finish in any desired color by spray-painting them with cellulose-acetate or cellulose-nitrate based finishes; or, a polished, color finish can be applied by impregnating glass mat with a resin to which the color has been added, and bonding the mat to the laminate in the mold.

In machining glass-plastic laminates, ordinary machine shop equipment is used, but at higher speeds



SPECIFIC TENSILE STRENGTH VARIOUS MATERIALS

than in the machining of metals. The mechanic who could make a part if it were metal can, with a little experience, does an equally workmanlike job on glass-plastic laminates. For longer tool life, carbide or carbide-tipped tools should be used.

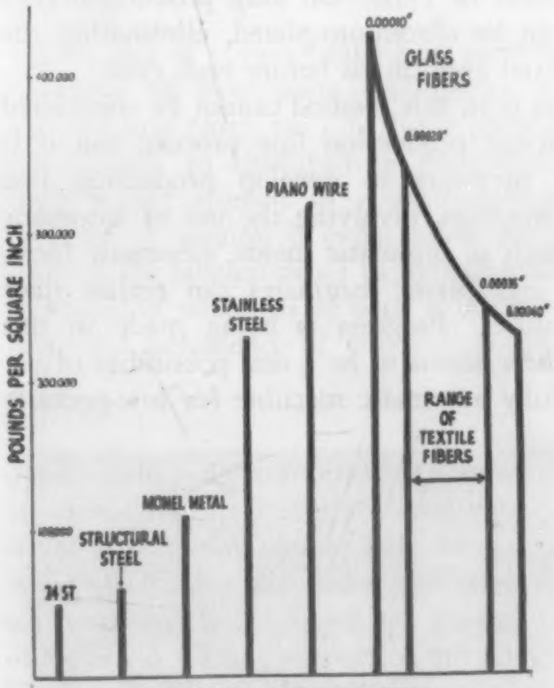
Plane Defroster Ducts

An example of how the use of glass-plastic laminates can simplify fabrication of compound-curve parts is provided by the defroster ducts for B-29 bombers. These ducts were originally made of aluminum, tailored to a tortuous pattern necessitated by the fuselage design.

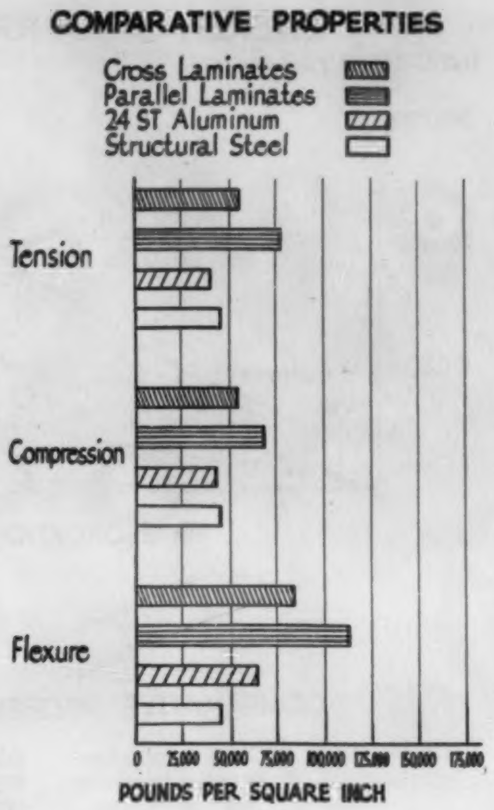
The variety of the duct sections and their different dimensions prohibited the use of costly molds, for no one section was to be produced in such quantities as to make the necessary financial outlay a sound investment. The longest sections measured about 45 in. and had 17 compound curves. Diameters ranged from ½ to 9 in. The sections, individually and assembled, had to be held to a tolerance of 0.030 in. An exact juncture with other plane fittings was required.

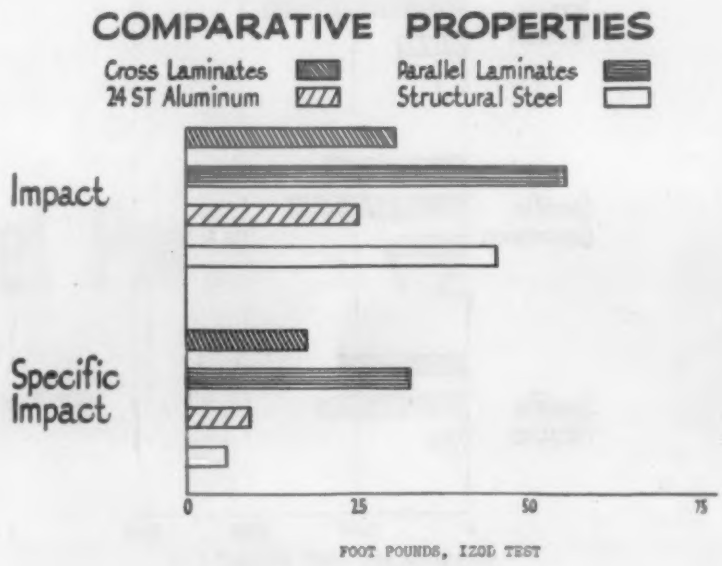
Any material to be used for ducts had to possess the properties of light weight, dimensional stability, close tolerances, easy manipulation and workability. At the same time, it must produce ducts that would have high impact strength and high resistance to heat, vapors and moisture.

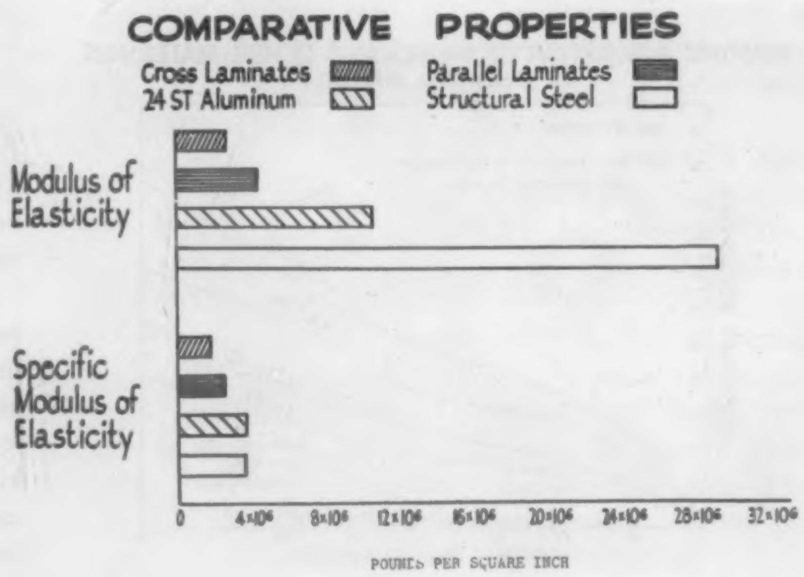
A glass-plastic laminate proved to be the answer. Tests of the glass-plastic ducts conducted by the fabricator included exposure of the ducts to temperatures in excess of 300 F for 6 hr. without distortion of dimensions. Other tests showed the ducts to have an impact strength of 50 ft.-lb. per sq. in.

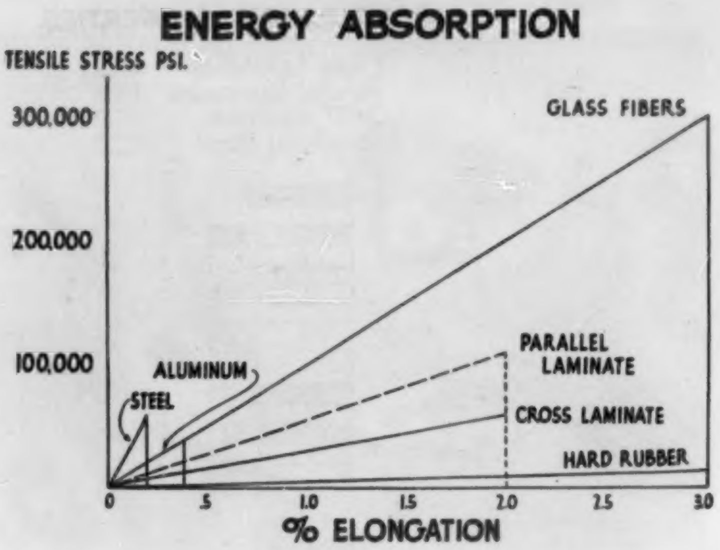


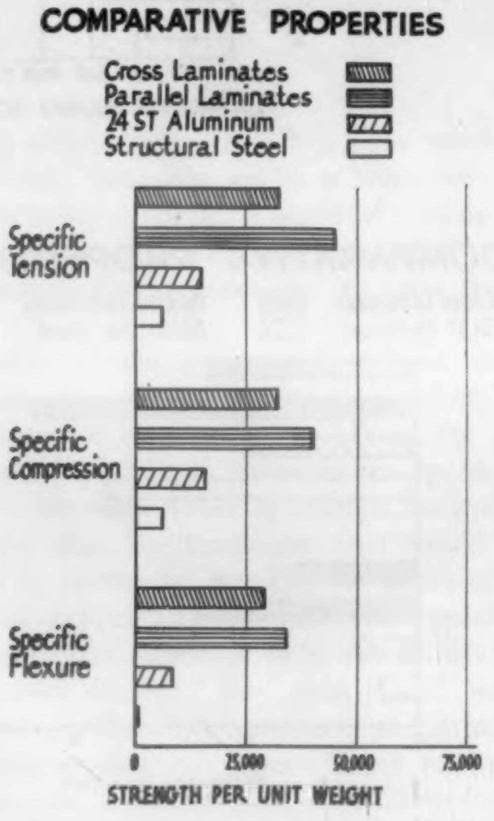
TENSILE STRENGTH
VARIOUS MATERIALS

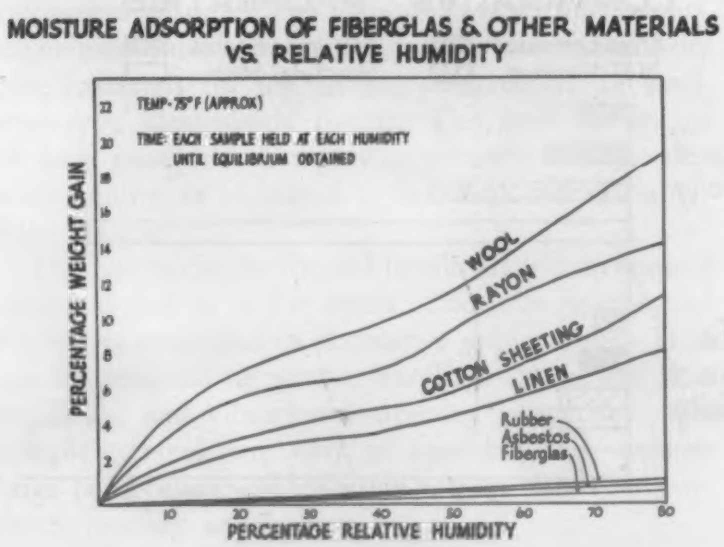












Methods of fabricating such parts as glass-plastic air duct sections can differ widely in detail, but a general idea of the process can be obtained from the following outline.

The first step is the preparation of form blocks. A plaster of Paris cast is made of a wood pattern of the part. A slush-molded core is then lifted from the cast. This is used as the form over which the resin-impregnated glass fabric is laminated. The hollow plaster core is insulated from the resin with Cellophane, or by a coat of lacquer followed by a coat of polyvinyl alcohol solution.

The required number of pieces of glass cloth are then trimmed to fit the form block. In cases of extreme compound contour, flutes are cut in the cloth to prevent wrinkling. A piece of the cloth is wrapped on the form block and the liquid resin is brushed into it. Successive pieces of the cloth are added and brushed with the liquid resin until desired thickness is obtained.

Heat and pressure required for curing can be applied by several methods. Pressure is needed only to keep the laminations in close contact with each other. A widely used method of applying heat and pressure is with the autoclave, but use of a vacuum bag in combination with an oven is becoming standard practice.

When the autoclave is used, the plaster core with its laminated covering is encased in a bag of polyvinyl alcohol, or is wrapped in Cellophane, to keep the laminate from adhering to a rubber bag in which core and laminate are placed. All air is exhausted from the bag. The entire assembly is then placed in the autoclave and heat and pressure are applied through the bag, either by steam or hot water.

Whatever the method, the form blocks or molds can be made of inexpensive materials. Concrete, wood, low-melting alloys, or plastics can be substituted for plaster of Paris. On long production runs the molds can be chromium-plated, eliminating the parting material application before each cycle.

Effective as it is, this method cannot be considered a highly efficient production line process, and it is undoubtedly necessary to develop production line fabricating processes, involving the use of automatic machinery, such as automatic molds, automatic feeds, etc., before glass-plastic laminates can realize their full potentialities. Progress is being made in this direction. There seems to be a real possibility of developing a fully automatic machine for low-pressure molding.

Present peacetime applications of glass-plastic laminates are relatively few. Designers and engineers are now studying use of glass-plastics for such products as railroad car, bus, automobile and truck body parts; for boats and canoes; for luggage and furniture; for kitchen and bathroom accessories and for home appliances. Use of the material in civilian plane parts will be a natural transition from its use in war planes.

Fig. 1 — Copper-brazed joints proved completely satisfactory in producing the M-74 bomb casing assembly and in the tail cup, tail plug and tail assemblies.

Electric Furnace Copper-Brazing of Steel Parts

by H. M. WEBBER, *Industrial Heating Div., General Electric Co.*

THE use of copper-brazing in assembling different types of steel parts (stampings, tubing, screw-machine parts, etc.) to form products impossible or difficult to manufacture economically otherwise was widely applied in war production. The same method of joining is expected to play a prominent part in the fabrication of peacetime products. A good example of what can be done is afforded by the practice and experience of two companies who applied electric furnace copper brazing in the manufacture of the M-74 C.W.S. incendiary bomb.

Many peacetime applications of copper-brazing are anticipated because of the success of this method of joining steel parts for difficult service conditions.

This bomb casing assembly was highly adaptable to fabrication by brazing. Too, there were three sub-assemblies in the tail piece that were also brazed in large continuous furnaces at high production rates. Quality was equal to—or better—and cost lower than that obtained by any other method.

Methods described in this article, which is concerned chiefly with tail-cup and tail-plug assemblies, are those used by Shwayder Bros., Inc., Denver, Colo., and in the International Nickel Co. plants at Meriden and Wallingford, Conn.

Joints made by copper-brazing had to be strong and ductile to withstand landing impacts and explosions. In addition, they were required to be perfectly tight in order to retain gasoline, white phosphorous and other materials. An accompanying illustration shows an M-74 casing assembly and its tail piece, together with the three sub-assemblies.

Fig. 2—The tail cup assembly is made of a hub and disk (left), assembled with a copper wire ring around the hub into a straight-walled cup (upper center) or taper-walled cup (lower center).

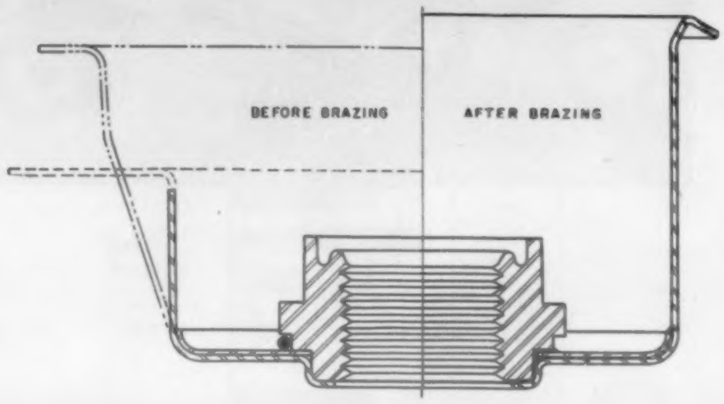


Fig. 3—Here is how the components and brazing metal shown in Fig. 2 are assembled and how the copper penetrates uniformly throughout all the joints (right).

Tail Cup Assembly

The tail cup assembly consists of two thin stampings and a screw machine part, all of SAE-1010 steel. The finished cup is about 2⅝-in. in dia., 1¾-in. deep, with a flange around the top about 3⅛-in. in dia. Total weight is approximately 5½-oz. In the bottom of the cup is copper-brazed a reinforcing disk with a hole in its center and turned-up edge, plus a screw machine part called the "hub." The hub is turned from hexagonal stock in order to provide wrench grip, to be used during insertion of the tail-plug assembly when the bomb is being loaded. This hub is pressed through the hole in the disk and into a recess in the bottom of the cup.

During the copper-brazing treatment, the steel becomes dead-annealed, which in most cases is desirable. However, it was felt that greater hardness around the rim of the tail cup is preferable in order to obtain the maximum tightness in the sealing operation. Inasmuch as cold working of soft metals hardens them, such work-hardening procedure was adopted in production to harden the rims of these copper-brazed tail cups. Two different schemes are used, both of which accomplish the same purpose. Shwayder Bros. draw the cup with sides which taper out to a rim diameter larger than that finally required. The assembly is copper-brazed in this form and then redrawn after brazing to the finished size and shape, which brings the hardness around the rim up to specifications. International Silver draws the cup 1-in. deep, with vertical sides, leaving the remainder of the blank undrawn and appearing as a ¾-in. wide horizontal

Fig. 4—Three trayloads of sub-assemblies about to enter the roller hearth furnace at Shwayder Brothers plant. Tail cups are double-decked for best efficiency.

flange. The disk and hub are then inserted and copper-brazed into it. The final draw after brazing easily gives the desired hardness. Typical hardness data, measured on the side, near the rim of the cup as Rockwell 30-N and converted to Rockwell B, are as follows:

Before brazing—74B
After brazing—39B
After brazing and redrawing—82B

Application of the brazing metal is simple and inexpensive. A shoulder is provided around the hub to accommodate a round copper-wire ring adjacent to the joint between the hub and the disk. This shoulder is $^3/_{32}$-in. wide and the ring is 0.072- to 0.081-in. dia. copper wire. If the round ring were not employed and the hub were hexagonal at the junction with the disk, a hexagonal ring would be necessary. Hexagonal rings are relatively difficult to form, to keep in shape, and to assemble. If they are not in good shape to fit snugly all around, the brazing metal might creep away from the joints instead of into them. The round rings, on the other hand, are easy to form, to keep in shape, and to assemble. Inasmuch as the round ring fits snugly on the round shoulder of the hub, all the brazing metal goes into the joint where desired. Not only is the hub brazed to the disk and to the cup by this ring, but the same copper also creeps out through the joint between the disk and the bottom of the cup, leaving a copper fillet entirely around the outer seam. Thus a single ring of copper wire supplies the entire amount of brazing metal for the job.

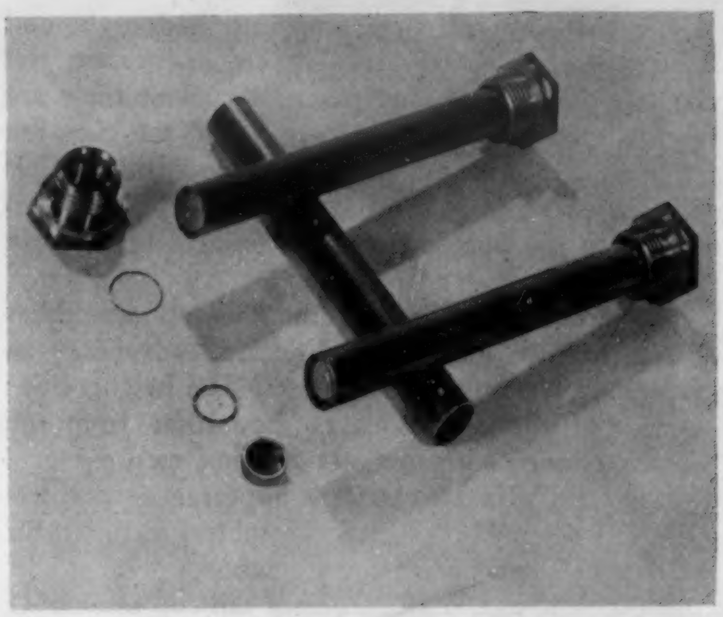


Fig. 6—In the tail plug assembly, a steel screw machine part, a stamping and a section of tubing are assembled with two copper wire rings and then brazed.

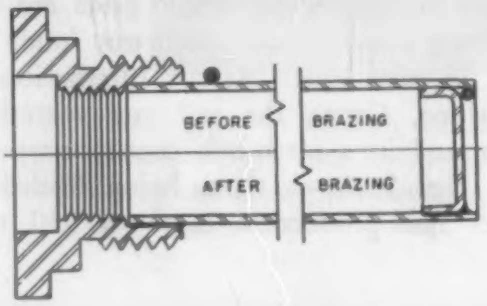


Fig. 7—The copper rings are preplaced in assembly and then when the complete assembly is in the electric furnace, the copper penetrates through the joints as shown.

Fig. 5—At International Silver Co., Meriden, Conn., plant tail cup assemblies are copper brazed in this mesh belt, conveyor-type, controlled atmosphere electric furnace.

The furnace brazed tail cups are both tight and strong. Rejections for leaks in an air-pressure test run less than 0.20% and practically all of these are rebrazed and saved. In a strength test, the cups are set upon a cylindrical support whose inside dia. is 2 in., outside dia. 2⅜ in. A load of 7000 lb. is then applied to the hub. Mechanical failures in this test are rare.

The uniform heating of the tail-cup assemblies during furnace-brazing is a decided advantage in keeping distortion to a minimum. The bright, clean surfaces of the assemblies as they come from the furnace eliminate cleaning operations, step up production, and give an excellent appearance. Furthermore, the cost of brazing the assemblies in this manner is lower than by any other method.

In Fig. 4 is shown a trayload of tail-cup assemblies ready to enter a roller-hearth furnace at the Shwayder Bros. plant. The tail cups are double-decked for maximum loading efficiency and rest on ribbon-mesh grids on channel-type trays. Grids also separate the two layers of assemblies. These grids are made of heat-resisting alloy ribbon. Each tray holds 128 tail cups, 64 in each layer. At the International Silver Co., Meriden, Conn., the tail cup assemblies are copper brazed in a mesh-belt conveyor-type electric furnace. Fig. 5 shows them being loaded on the conveyor. The production is about 950 tail cups per hr.

Tail Plug Assembly

The tail plug assembly is made of three SAE-1010 steel parts, a tube, a screw-machine part, and a stamping (Figs. 6 and 7). The tube is pressed into the screw-machine part and the stamping is pressed into the opposite end of the tube. Both joints are then copper-brazed in a continuous electric furnace. The assembly weighs about 3½ oz.

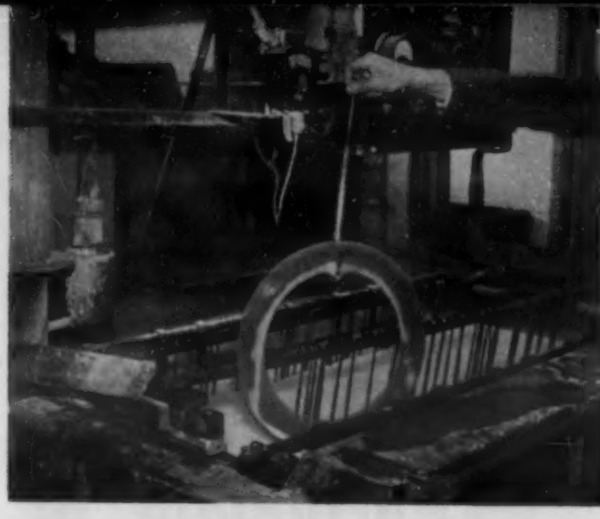
The tube is about ⅜-in. in dia. and 5¼-in. long. The screw-machine part, or "plug," is made from hexagonal stock 1⅛-in. wide and ¾-in. long. The cup is about $^9/_{16}$-in. in dia. and $^3/_{16}$-in. deep. The end of the tube which receives the cup is swaged open on a slight taper. With the cup pressed in, the cup does not drop down further as the tube heats up and expands during the brazing operation.

Applying the brazing metal consists simply of placing a ring of 0.020-in. hard copper wire around the tube near the plug, and another ring of 0.032-in. copper wire inside the tube on the top of the cup. The assemblies are set on pins on cast-bar trays such as shown at the extreme left in Fig. 4, ready to enter the roller-hearth furnace, at Shwayder Bros. or laid on the conveyor of the mesh-belt furnace shown in Fig. 8 at the International Silver Company's Meriden plant.

The mesh-belt furnace (Fig. 8) is used for brazing both the tail plug assemblies and tail cup assemblies, and occasionally for brazing casing assemblies. It has a belt of 12-gage, heat-resisting alloy wire, 20-in. wide and woven with ⅜-in. mesh. The furnace is rated 100 kw. It has a door opening 10-in. high, a heating chamber 8-ft. long, and a cooling chamber 24-ft. in length, with two power control zones in the length of the heating chamber. Its capacity is 700 lb. gross per hr. at 2050 F, including the work and the belt.

Fig. 8—Here is the way in which tail plug assemblies are loaded on the conveyor of a continuous copper-brazing furnace. Two operators, one at each end of the furnace, braze over 900 assemblies an hour.

Compressed Air Speeds Powder Metal Forming



Gas and compressed air are mixed to heat this alkali solution for cleaning steel backing plates before electroplating. The immersion burner is at left.

Quick traverse for this molding press is obtained by a turn of air line lever. The air loads the oil accumulator tank (behind operator) 60 times faster than with hydraulic pump. Presses like this one mold powder metals for bonding to backing plates.

THE WIDENING APPLICATIONS for powder metallurgy are creating an interest in the processing methods used to bond powdered metal into tough, serviceable, friction material. Noteworthy in these processes is the manner in which compressed air is employed at the plant of the S. K. Wellman Co., Cleveland.

This company makes clutch facings and brake linings for trucks, farm machinery, airplanes, machine tools and other heavy-duty equipment. The first step in preparing steel backing plates for powder metal surfaces is to wash them for electroplating.

In cleaning plates in a bath of heated alkali solution, compressed air and gas are mixed for the thermostatically-controlled immersion burner which heats the solution to 200 F and holds it at that point. The necessary jet effect for the flame is obtained by compressed air as well as the improved combustion resulting from the proper mixture. The same type of jet burner is used in the pre-cleaning process. After washing and acid cleaning, the backing plates are electroplated.

In preparing the powdered metal for sintering, various kinds of metal are first thoroughly mixed to insure a uniform blend. Predetermined amounts of the mixture are then placed in molds and hydraulically compressed to semi-finished form. To maintain production speeds, each of the 10 presses is equipped with a compressed air-operated quick traverse. This traverse brings the mold into position in a number of seconds comparable to the number of minutes which would be required were a hydraulic pump used in the operation. The quick traverse operates by loading the oil accumulator tank with compressed air for pressure to rapidly raise the cylinder. As a mold press is re-loaded every 10 min., the quick traverse is an important production factor.

If one step in production can be called more important than another, the most important process comes after compressing. At this point the semi-finished powder metal pieces are pressed in especially-built electric furnaces where they are sintered and welded to steel backing plates. Approximately 75 rings, the number varying according to size, are placed in a furnace and a combination of heat and pressure bonds the powder metal to the backing plate to make it an integral ring, ready to withstand friction and hard usage.

Applications of air include cleaning, forming and bonding to backing plates.

In designing these furnaces, the S. K. Wellman Co. decided upon compressed air to supply the constant pressure of about 100 psi. on a ring, because it automatically adjusts itself to the slight sag which takes place over the 5 to 7 hr. heating cycle. Other types of pressure would have to be adjusted by involved mechanical or by manual methods as the sag increased, it was explained.

Does this combination of heat and pressure work? The answer to that can be seen in the company's laboratory. Here, a large dynamometer can closely duplicate the speed and impact of an airplane landing and the vantage point for seeing and recording the burning, crunching punishment taken by an airplane wheel hitting the ground at 100 m.p.h. is better than in an actual landing. After 25 simulated landings, the brakes made from a series of these bi-metal rings are examined and the tests show that the team of heat and compressed air pressure have done a good job.

Subzero Treatment Simplifies Hardening of Alloy Carburizing Steels

by H. E. BOYER and H. C. MILLER, *American Bosch Corp.*

SUBZERO TREATMENT and its value in transforming retained austenite and the subsequent dimensional stability of hardened steel parts has been a project to which a great deal of metallurgical research has been devoted during the past several years. Particularly during the past four years the results of such research work have been widely published. Such publications as the paper presented by Messrs. Fletcher and Cohen at the twenty-sixth Annual Metal Congress have been of outstanding academic interest as well as great practical value to manufacturers. Up to the present time, however, it seems that the emphasis has been focused on the steels of high carbon content or high alloy types including the various high speed steels. Apparently very little attention has been paid to the carburizing steels of either the straight carbon or alloy types.

As authors of this article we do not profess to be authorities on the subject of subzero treatment, but our work along this line started early in 1939, when we found that the problem of dimensional stability was very serious in making and holding extremely close tolerances on parts of the martensitic types of stainless steels. Such tolerances are frequently necessary in the manufacture of certain precision parts. Since the start of this work we have been constantly working with subzero treatment and its subsequent effects on many different types of hardened steels. Our most recent work, however, has been entirely with the higher alloy types of carburizing steels. The text of this article is therefore confined to results we have obtained on E-3316 steel which has long been known to be one of the worst offenders in the tendency to retain austenite at normal room temperature. It is the hope of the authors that this information may be helpful to others in producing parts from steels which are known to have a very low M_F point, so that such parts will be free from retained austenite and in a stabilized condition after heat treatment.

Hardness tests and metallographic examination prove that low temperature treatments stabilize carburizing alloy steels.

There is no doubt that the practice of subzero treating of steels has been used and abused in much the same manner as have many other processes or parts of processes through the years. It would indeed be an exceptional case if, when some new phenomenon were discovered or a new technique developed that, it could be dispensed only with complete and accurate information. Thus, it would be used only with intelligence and for the purpose to which it would be best adapted. The subzero treatment has been no exception to the rule. It has gone or at least is going through the usual cycle of industrial experimentation after having been introduced to the public. We think of such a cycle of industrial experimentation after having been introduced to the public as consisting of three stages. First, a new process which, beyond a doubt possesses a great deal of merit, if properly handled, is introduced to industry at which time it is once thought by many to be the "cure for all evils" occurring in industry all through the centuries. Frequently such a process through exaggerated reports from over-enthusiastic investigators gains entirely too much momentum. This builds-up for a later fall.

We regard the second stage of the cycle as being the period during which the process has been considered by many to be a flat failure in accomplishing some of the feats which the manufacturer expected. This is usually due to false information even though the originators were probably shuddering at the thought of such accomplishments being expected. During the time the sudden interest usually decreases and the process receives a temporary set back from industry because it could not perform the miracles which were anticipated. The third stage is the period during which the first enthusiasm has died down and the general interest is again focused on the industrial

horizon, watching for some new miracle producer. During this time development work is carried on by more practical investigators who do sound thinking and work with scientific caution. The new process itself is then applied with more intelligence and to the accomplishment of the work for which it was originally intended.

From our observations it seems apparent that the subzero treatment of steels has now entered the so-called third stage. One still hears such typical questions as, "How much austenite can be transformed?" "How must the cycle of operations be carried on so that maximum benefit can be obtained from the low temperature treatment?" "How long must parts be kept at the subzero temperature?" "Will parts be likely to crack if subjected to the subzero temperatures immediately after the quench?", and other such logical questions.

It is our hope that the data which we are giving in this article may be of some help in answering or at least partially answering some of these typical questions.

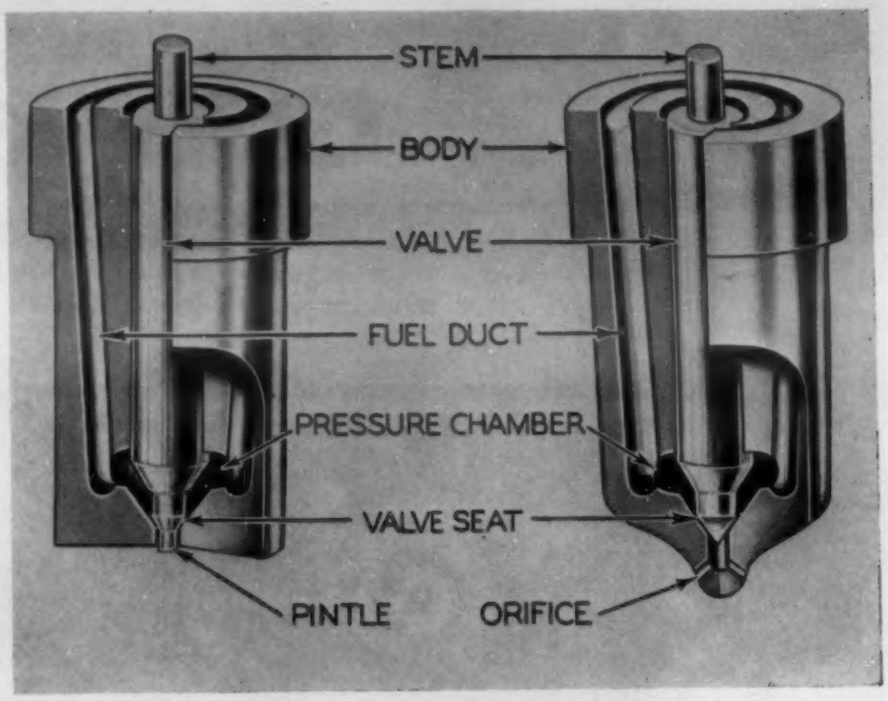


Fig. 1—On parts of this type stabilization is important during both manufacture and use.

Practical Advantages of Stabilization

Many manufacturers have the problem of how economically to produce precision parts which will maintain close dimensions not only during manufacture but after they are put into service. At a glance this does not appear to be a problem of great magnitude though after one considers the number of variables that are certain to be encountered the process at once seems to be quite complicated. Variations in the type of steel, including analysis, mill practice and machining coupled with heat treating variables and the ever present human element all have the most decided effects on the final results. Of all these variables the human element and the heat treatment are probably the major ones. These two go hand in hand and have long been regarded as the most difficult.

Very often large sums of money are spent by a manufacturer in order to machine a part to close tolerances and then he may spend only a small amount on its heat treatment. Later the part may be thrown away or it possibly may pass inspection and then fail miserably in service. In spite of all the engineering and fine machining, the part is no better than its heat treatment. Such a part does not necessarily have to crack in hardening, break in service or wear out, to be a failure. A permanent dimensional change occurring at room temperature or higher in a precision part can be equally as guilty in causing the part to function improperly or not at all. This unstable condition can be due to any one of the above mentioned variables. Usually, however, it is due to the retention of austenite.

How does anyone know whether austenite was retained when the part was hardened? Unfortunately, this condition is unknown except in extreme cases and it is a settled fact that one could not section each piece and examine such by means of a metallurgical microscope. It therefore becomes more practical to assume that all hardened parts do retain austenite at room temperature and then take the necessary steps to eliminate the condition—at least on all parts which must remain stable in operation. Retained austenite has long been a problem in the carburizing and subsequent hardening of high alloy carburizing steels and usually requires an expensive heat treating cycle to eliminate the condition. Even then whether or not this condition is effected is always problematical. Obviously any method which will eliminate this condition in an economical manner and be reasonably accurate is much desired.

As an illustration, the authors had a part as shown in Fig. 1. This part required uniform heat treatment with minimum distortion and maximum stability. Any retention of austenite is very detrimental in the final lapping of the valve hole because heat generated in lapping makes it difficult to control size. Fig. 1 actually shows two different types of parts though they are made of the same material and with the same accuracy. The parts under discussion are those marked "body." The valves which are the mating parts also shown in the illustration are fitted with an allowable tolerance of 0.00008 in. Any material which is unstable at room temperature or at operating temperature which is somewhat higher will cause the valve to operate improperly or freeze completely thus making the assembly worthless.

Treating Procedures

Standard practice in the heat treatment of such parts has been to pack carburize; slow cool to room temperature; reheat in protective atmosphere; quench in oil, temper for 2 hr.; subject to low temperature for 2 hr.; and then retemper for 1 hr. While this method proved reasonably satisfactory, it was found necessary to increase production and, if possible, to increase

Figs. 2, 3, 4, 5, and 6—Photomicrographs taken after varied heating and cooling cycles to determine degree of retention of austenite.

FIG. 3

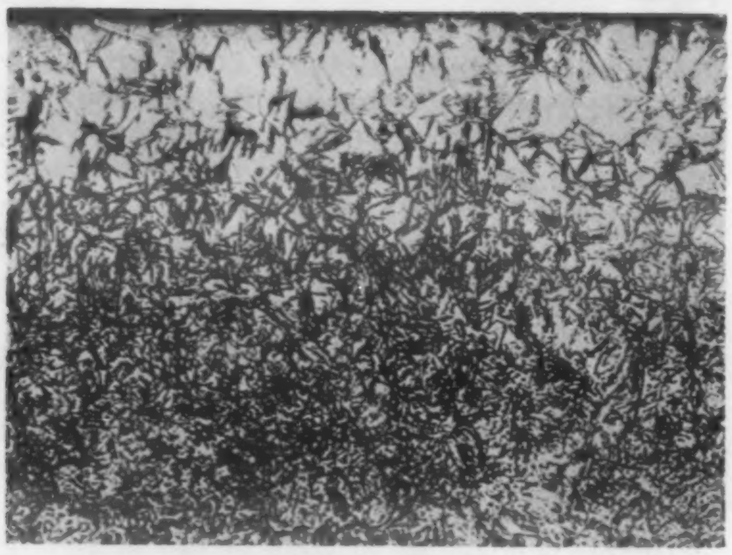


FIG. 2

the degree of stability. We have tried gas carburizing, using many different carburizing cycles, salt carburizing, Martempering, etc., and found that a low temperature treatment was indispensable irrespective of the method of carburizing and hardening if maximum transformation was to be affected. Low temperature treatment used in conjunction with the heat treating cycle is simple, economical, and provides excellent insurance that a stabilized part will be obtained.

The photomicrographs shown in Figs. 2, 3, 4, 5, and 6 substantiate this statement. They show results obtained from a heat treating charge which was run during the earlier part of this investigation. This heat treatment was carried on in a standard Leeds & Northrup Homocarb furnace using the cracked dipentine atmosphere. The parts were carburized for 1 hr. at 1650 F. The dipentine was pumped into the furnace at a rate of 120 to 130 drops per min. for the car-

FIG. 4

burizing period and then turned off completely. The oil flow was then allowed to remain turned off for ½ hr., but a furnace temperature of 1650 F maintained. This allowed the case to diffuse rather than to absorb more carbon thereby lowering the surface carbon content. At the end of the diffusion cycle the dipentine flow was turned on and allowed to run at 60 to 70 drops per min. to maintain a protective atmosphere—thus preventing the formation of scale. The control pyrometer was then set to 1450 F (the quenching temperature) and the furnace allowed to cool. This temperature was then maintained for 1 hr. to make certain that the whole charge had assumed the temperature of 1450 F. The charge was then quenched directly into oil at room temperature. One actual part was cut into sections and treated in various manners in order to produce the structures as shown in the photomicrographs.

Results

Fig. 2 is a photomicrograph of a cross section of the case taken at 350X. The edge of the specimen in all illustrations is shown at the top of the pictures. It can be noted by the tabulated data (Fig. 7) that the hardness of this specimen is Rockwell 59 C but measures only 83 on the 15N scale indicating that the superficial hardness is very low, a fact that is well borne out by the large amount of retained austenite existing in the outer layers. This structure shows only a relatively few martensitic needles in a matrix of austenite.

In another photomicrograph, Fig. 3, also taken at 350X, of a portion of the same test specimen as used for Fig. 2. The only difference in the treatment was that this specimen was tempered for 1 hr. at 300 F. It will be noted that the Rockwell C hardness dropped to 56 though the superficial hardness remained the same. The microstructure is essentially unchanged.

The same specimen shown in Fig. 2 is shown in

FIG. 5

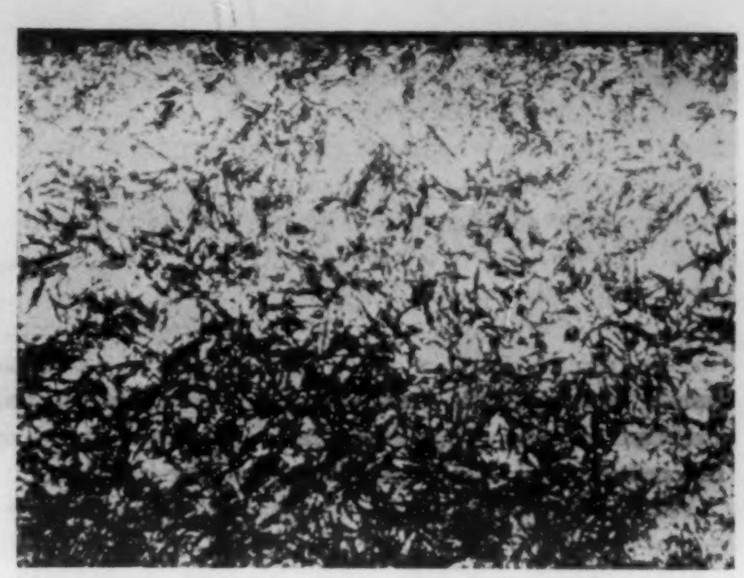


FIG. 6

Fig. 4 except it was rephotographed after having been subjected to −120 F for 3 hr. From the table in Fig. 7 it will be observed that the actual Rockwell C hardness has increased to 64 and that the superficial hardness also increased from 15N-83 to 91 or from 45 to 62 Rockwell C by conversion. The transformation brought about by the low temperature treatment is quite evident by the photomicrograph.

Fig. 5 is another photomicrograph taken at 350X of the same specimen used in Figs. 2 and 4 except that it was tempered for 1 hr. at 300 F following the low temperature treatment. The microstructure in this photograph shows a still more complex transformation, especially at the edge of the carburized case. This is indicated by the superficial hardness of 15N-91.5 (equivalent to Rockwell 63 C) though the actual Rockwell C hardness had decreased slightly, to 62, after the tempering operation.

Fig. 6 is another photomicrograph also taken at 350X. This one is actually the same specimen which was used for Fig. 3 except that it was subjected to −120 F for 3 hr. following the tempering operation at 300 F before it was rephotographed. There is a very noticeable change in the microstructure from Fig. 3 as affected by the low temperature treatment though it is not as completely transformed as in the case where the subzero treatment was used prior to the tempering operation. This is also substantiated by the hardness readings from the table in Fig. 7. Investigation further proves that maximum benefit can be obtained by subzero treatment only if used immediately after the quench and prior to tempering in the cycle of operations. This has already been reported by other investigators.

Subzero Treatment Cheaper

Our purpose in publishing these results is actually two-fold. First, to further prove that retained austenite can be transformed by subzero treatment, and second, to offer a relatively quick and accurate method for carburizing and hardening such steels as E-3316 which have very low M_F points and consequently tend to retain large percentages of austenite. It is obviously much more economical to use a subzero treatment rather than to run long diffusion cycles after the carburizing cycle. Even if we could be assured that complete transformation could be obtained by long heat treating cycles, or by cooling slowly to room temperature and reheating to harden, it is an expensive process. In addition, from our experience it is

HARDNESS TEST DATA

FIG. NO.	TREATMENT	HARDNESS ROCKWELL-C	HARDNESS ROCKWELL-15N	ROCKWELL-C CONVERTED FROM 15N
2	AS QUENCHED	59	83	45
3	QUENCHED & TEMPERED AT 300°F.	56	83	45
4	QUENCHED & TREATED AT 120°F.	64	91	62
5	QUENCHED, TREATED AT −120°F. & TEMPERED AT 300°F.	62	91.5	63
6	QUENCHED, TEMPERED AT 300°F. & TREATED AT −120°F.	60.5	90	60

Fig. 7—Hardness test data for specimens shown in Figs. 2 to 6 inclusive.

extremely difficult to obtain uniformity. Fig. 8 shows graphically the time and sequence of the heating and cooling operations described in this article. The various points at which the photomicrographs were taken are also shown on this chart. It is quite evident that this heat and cold treating cycle is simple and rapid. Total case depth obtained from the 1 hr. carburizing cycle was 0.028 in.

In attempt to answer some of the common questions asked and mentioned earlier in this article, we must state again that we do not profess to be final authorities on the subject and that we can only give the results of our experience on the subject.

As to the amount of austenite which can be transformed at -120 F we do not exactly know. We feel that this is somewhat dependent on the length of time which is consumed in being cooled from the austenitizing temperature to the low temperature. Messrs. Cohen and Fletcher have already proven that further transformation can be obtained by the extremely low temperatures of -150 to -200 F or even lower. So far, however, -120 F seems to be about the lowest temperature that is practical to maintain for production purposes. As has already been stated and proven by our photomicrographs, there is no doubt that parts should be cooled immediately after the quench and before they are either tempered or allowed to age for any length of time at room temperature. Just what this length of time is we do not know. But we feel that the subzero temperature should be used as quickly as a practical cycle of operations will permit. We also have obtained a great deal of benefit by using the subzero treatment a number of hours or even up to a week after the part was quenched, thus indicating that this time factor is not too critical. It does seem apparent that we must have obtained nearly 100% transformation in the specimen shown in Fig. 4 since Rockwell 64 C is certainly very close to the maximum that can be obtained on carburized E-3316 steel.

As to the length of time required at low temperature we have not as yet obtained any definite proof, though our experience has shown that it is not necessary to allow any more time than is necessary for the work to assume the temperature of -120 F. We allow 3 hr. after the recorder has reached -120 F though this may be somewhat longer than is actually necessary. So far we have never found a second cycle of the low temperature to be of any value.

As to the danger of cracking in hardened parts which are subjected to the low temperature without any stress relieving, we all know that this has been a much debated subject. All we can say is that we have never experienced a single case of cracking that can in any way be attributed to this practice. We are, however, quite careful in loading the freezers so that none of the parts touch the sidewalls or bottom of the low temperature compartment. In all cases we use a medium of air rather than any liquid so that the work itself is not lowered rapidly in temperature. The work is all loaded in suitable trays or baskets so that the above procedure can be carried out.

There is no doubt that benefits are accruing from results of research work done on this subject during the past seven years. It does seem that as great or perhaps greater benefits can be derived from its use on the alloy carburizing steels than on some of the other types discussed at great length previously.

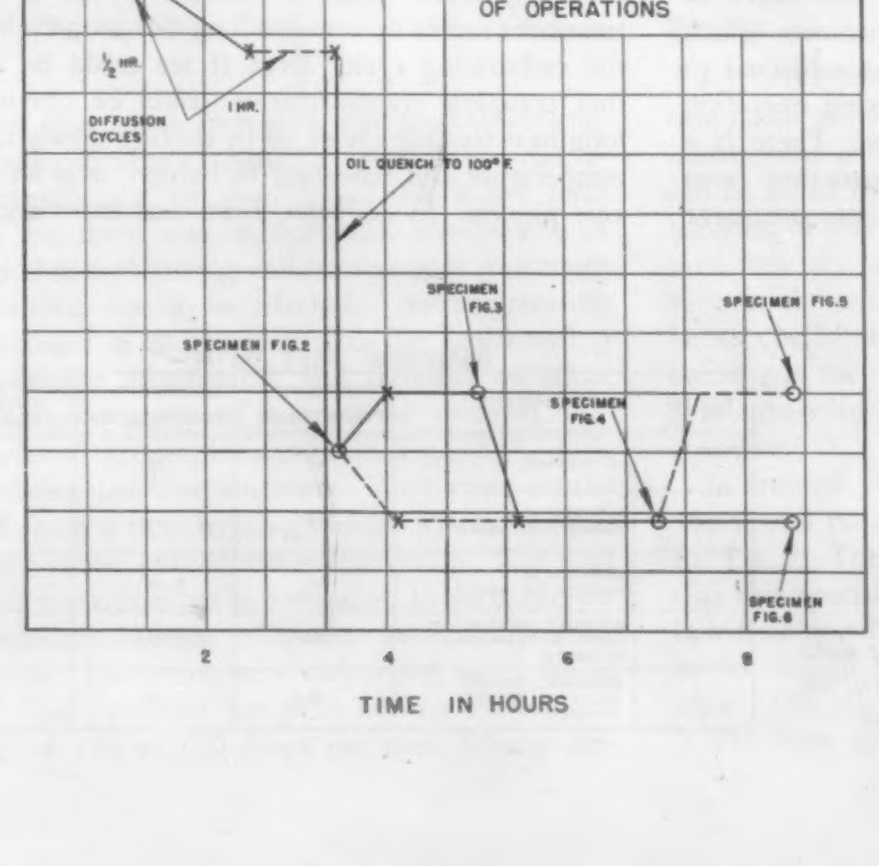


Fig. 8—On this chart are indicated points at which specimens were taken for study.

CONTENTS NOTED

A monthly department dedicated as a forum for the interchange of ideas between readers and editors. All readers are urged to take advantage of this space and participate in the discussions presented.

Noah vs. Daniel Webster

To the Editor:

I didn't realize that Daniel Webster was an authority on metalworking as well as having his more obvious talent as an orator. However, your October 1945 issue (page 1136) gives *Daniel* Webster's definition of peening. On second thought, maybe Daniel didn't know a peen from radar; it may be that your office bibliographer had a day off when that piece passed through and Noah Webster failed again to get his proper credit.

Peter T. Harold

New York, N. Y.

This just demonstrates what publicity can do. While Noah Webster is famed for compiling one of our standard dictionaries, he has been less publicized through the generations than Daniel Webster. Thus, Daniel often gets the bow when Noah did the work. We apologize to our readers and to Noah.—The Editors.

Iron-Aluminum Corrosion

To the Editor:

We are joining some iron tubing ends onto aluminum tubing which is being used for irrigation systems.

Please advise whether or not we will be troubled with electrolysis between the iron screws and the aluminum.

W. H. Harold

Harold Electric Co.
Walla Walla, Wash.

Although it is unsafe to make predictions about corrosion behavior in the absence of complete information, in our opinion there is likely to be galvanic corrosion in the setup described. The attack will be less severe if the iron were replaced with copper. Pure aluminum (2S) would be attacked faster than aluminum alloys such as 17S or 14S.—The Editors.

Supersonic Testing

To the Editor:

In the January issue of MATERIALS & METHODS the supersonic method of testing is discussed in two places, namely, on page 84 in the right-hand column and on page 146 in the left-hand column. In both places the statement is made that the supersonic inspection method consists in the use of ultra-high-frequency radio waves. This is incorrect. The supersonic waves which are used for testing are high-frequency sound waves and not radio waves. The quartz crystal which is used to generate the high-frequency sound waves by means of piezoelectric effect is excited by high-frequency radio waves, but the waves which are transmitted through the material to be tested are sound waves and not radio waves.

F. V. Lenel

Moraine Products Div.
General Motors Corp.
Dayton 1, Ohio

Reader Lenel is quite right in his correction—the waves transmitted through the material are sound waves. Two methods currently used rely upon the use of such sound waves. One uses a crystal transmitter which catches the reflections of the sound waves as they bounce back from the ends of the material or from flaws encountered. The other method employs a crystal transmitter on one side of the work and a crystal pick-up unit on the opposite side. Changes in density of the material caused by voids, inclusions and other faults change the value of the wave received.—The Editors.

Stainless Silver

To the Editor:

Your "Production Frontiers" review is always very interesting and generally I do not miss it. However, for one reason or another I skipped the November issue and only a few days ago I received a letter from a friend of mine in Paris who asked me what I know about "Stainless Silver" which, according to your information, would have been developed by the Japanese.

Being unable to answer the question, which by the way interests me also, I would appreciate it if you would tell me something more about Stainless Silver.

R. V. Volterra

General Plate Div.
Metals & Controls Corp.
Attleboro, Mass.

Several other persons have indicated

(Continued on page 739)


N-A-X
HIGH-TENSILE STEEL
DESIGNER'S CHOICE...
√ REDUCE MASS AND WEIGHT
√ INCREASE STRENGTH AND DURABILITY

CONTENTS NOTED

Continued from page 737

an interest in this material which came to our attention through the Foreign Commerce Weekly, *September 8, 1945. The two following letters from government officials throw a little more light on the matter.—The Editors.*

The first letter follows:

I have your letter relative to your interest in "Stainless Silver."

May I suggest that you repeat your inquiry to Dr. R. R. Sayres, director, Bureau of Mines, since the article had its genesis in that agency.

In my opinion, the use of the term "Stainless Silver" was rather ill-advised, unless it could be proved that it is a commercial product and can withstand the rigors of "shelf-age." Incidentally, there is no novelty in the use of the term. Over a period of years many United States letters patents have been granted to inventors of "Stainless Silver." This immediately begs the question—what is stainless? The term "substantially stainless" usually follows in the recital of claims.

W. A. Janssen
Chief, Metals and Minerals Unit
Department of Commerce
Bureau of Foreign and Domestic Commerce

Following Mr. Janssen's suggestion we received the following reply:

The article in the *Foreign Commerce Weekly* is a press release from the Office of Minerals Reports of the Bureau of Mines, based on a report for the State Department by Mr. Nelson Dickerman of the Foreign Minerals Div. of the Bureau of Mines. The Bureau of Mines has never done any work on stainless silver; however, the National Bureau of Standards did some work on the subject about 15 years ago and the reference together with a general review of corrosion resistance of silver and its alloys is given in the book "Silver in Industry," edited by Lawrence Addicks in chap. 15, of which Allison Butts of Lehigh University was the senior author. Patents are also listed, and other pertinent literature on the subject is in the bibliography.

Mr. Dickerman tells me that he found a statement about the Japanese work on stainless silver in the Far East Yearbook of 1941 published in English in Tokyo. It mentions a Dr. T. Tanabe as the inventor of a stainless silver alloy patented in the United States, England, Germany, France and Japan.

R. R. Sayres
Director
Bureau of Mines
U. S. Department of the Interior

The book suggested by Dr. Sayres, "Silver in Industry," is published by the Reinhold Publishing Corp., 330 W. 42nd. St., New York 18, N. Y. —The Editors.

Multiple Arc Welding

To the Editor:

The writer notes that in your review of welding in the January 1946 issue of MATERIALS & METHODS you touch briefly on the subject of multiple arc welding. Due to our need for improved welding methods for light gage aluminum alloy, we would appreciate it if you could, if possible, furnish a more detailed amount of information on this process as well as sources of this information.

H. J. Laiming
Eng. Prod. Division
Radio Corp. of America
Camden, N. J.

One of the first production applications of multiple arc welding was in putting the heads on 300-gal. gas tanks for planes. Material used was 0.081-in. 52S-½H aluminum. Each tank required 150-200 in. of welded seam.

Advantages claimed for the method include the fact that no shielding is required; there is little or no porosity in the weld; no preheat is required, and extremely close heat control is possible. One disadvantage is that the equipment requires more room for placing the weld so that it is not possible to weld in such confined areas as when gas welding.—The Editors.

Boron-Containing Cast Iron

To the Editor:

In your issue of January 1946, page 89, you mention the apparently new use of boron-containing cast iron in cylinder liners for slush pumps, etc. One of our principal operations for the past fourteen years has been the production of such an alloy and its application as a lining material in cylinders. These cylinders are used not only in the oil industry but enjoy extensive use in rubber and plastic working machinery. The metal and the method of application are covered by U. S. Patent Nos. 2046913, 2046914 and 1923075.

Oil Well Supply Co. is licensed by us to produce such liners and has sold them for many years under the name of Di-Hard. The Russian article from which your notation was derived is a literal translation of our patent.

W. F. Hirsch
General Manager
Industrial Research Laboratories, Ltd.
Los Angeles 15, Cal.

Because

These seven parts are all alike—alike because their *best method of mass production* is SINTEEL ferrous powder metallurgy.

They're alike because each can be molded in one pressing, without undercuts in more than one direction. They're alike because, by any other means of production, each would require so much machining that labor (and equipment) costs would be unreasonable. They're alike because each must have the properties of a steel—for hardness, or magnetic permeability, or physical strength. They're alike because each must be made in large quantities by automa ic means—to tolerances measured in thousandths.

Parts in *your* product might fit this same pattern. Parts in *your* product might be just like the seven shown above—in manufacturing characteristics, if not in form or function.

And the way to find out is to investigate.

Send us your parts for comment. Let's see if their present design (or a minor variant of that design) doesn't make them "naturals" for SINTEEL ferrous powder metallurgy—like these, which are "all alike."

JMLCo-AM-C1

Write, phone or wire.

AMERICAN ELECTRO METAL CORPORATION

YONKERS 2, NEW YORK

Offices in Chicago, Dayton and Detroit

POWDER METALLURGY SINTEEL FOR MASS PRECISION

MATERIALS & METHODS MANUAL

13

This is another in a series of Manuals on engineering materials and processing methods, published at periodic intervals as special sect .ıs in Materials & Methods. Each of them is intended to be a compressed handbook on its particular subject and to be packed with useful reference data on the characteristics of certain materials or metal-forms or with essential principles, best procedures and operating data for performing specific metal-working processes.

Precision Investment Castings

by EDWIN LAIRD CADY

During the war years the advantages of precision castings became known, indirectly, to many people. This naturally led to many ideas—some exaggerated—as to what could and what could not be produced by the "lost wax" method. Here is a comprehensive manual of the capabilities and limitations of precision castings as reported by production executives of the leading producers of precision castings, their suppliers and men holding patents on many of the processes involved.

Contents

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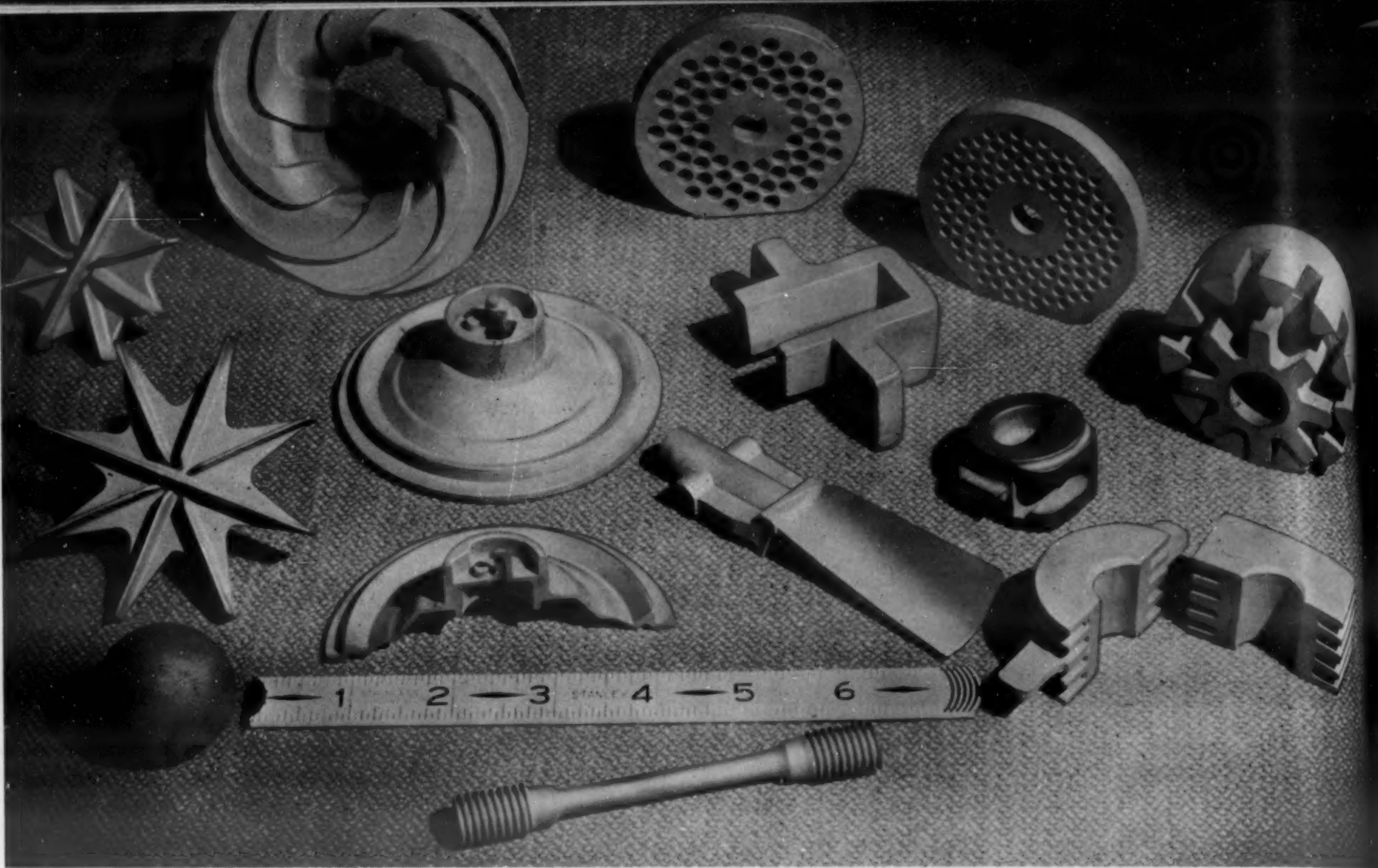


Complexity of parts produced by precision investment casting are illustrated in this assortment. (Courtesy: International Nickel Co.)

Introduction

Precision investment casting is solving so many problems for production men, parts designers and metallurgists that the rush to make use of it amounts to a boom.

It is a process which spent hundreds and perhaps thousands of years in its infancy. The "lost wax" method—its forerunner—was probably used by the Egyptians for producing statuary. Yet its first use as a modern industrial art appears to have been around the early 1930's in the production of jewelry, and only within the past four years has it been developed enough so that large numbers of metal parts makers would give it serious consideration.

With the exception of a baker's dozen of shops which have worked with individual phases of the process long enough to reduce them to controlled production line procedures every plant which is working with precision investment casting at all is doing so on an experimental basis.

New users of the process are being guided by the excellent sales engineering services of the makers and sellers of special equipment and supplies, and by professional consultants. Many supplies sellers are operators of plants and can first develop a procedure for making a given product, then take on a contract for its production, and finally sell the shop which uses the part a complete set-up for making it.

Equipment and supply houses also cooperate in the training of supervisory labor. In some cases they will take the men from the customer's shop and train them in their own shops. There is no floating supply of machine operators or of supervisory personnel trained in this process; too few shops have employed too few men to create such a supply. Some shops are finding excellent engineers among the army and navy officers who worked with precision investment casting when the process was desperately needed to produce turbine blades and other military products during the war.

In spite of the shops which have worked stainless steel, Stellite, jewelry and various nonferrous metal phases of the process into production line procedures, every phase of this process appears to be at least two years away from jelling into standard practices. New developments are coming along so rapidly that the art probably is ten years away from reaching the stability of procedures now enjoyed by forging, die casting, and sand casting.

Little of the process development is beyond the "cut and try" stage in which procedures for the production of a given part are worked out in pilot operations and then applied to the production line. But one of the great virtues of precision investment casting is that pilot operations can be carried out in only a few square feet of floor space, or can be tried on the production line itself without interfering with regular production.

Horizons and limitations of the process are nowhere in sight. And in spite of the slightly crystallized but generally amorphous state of its present development, precision investment casting is saving enormous sums of money and opening all sorts of new opportunities to machine parts makers.

General Description of the Process

Precision investment casting is a method of preparing a flask or "investment" which has cavities of precisely controlled contours and dimensions and is at a closely controlled temperature, and of filling this flask with metal which is melted and poured under precisely controlled conditions, thus producing highly accurate castings to close metallurgical specifications.

Each step in the process is aimed at producing an investment which will work ideally as a tool of the casting process. The casting process, usually centrifugal or else pneumatic pressure, can in turn be modified so that with a given alloy it will work best with the investment. Problems of the process are those of what the investment will permit the casting method to do rather than what the casting method will permit the investment to do.

To prepare the investment:

1. Study is made of the part to be made, to determine shrinkages and possible distortions in the casting operation, in the investment itself, and in the patterns.
2. Dispensable patterns are made of wax, of plastics, or of other materials which can be completely evacuated from the investment.
3. These patterns are fastened together in gangs or "clusters" with the necessary sprues for casting.
4. The clusters are placed in a flask and soft investment material is poured over them to fill the flask, air bubbles being eliminated by vibration and/or vacuum.
5. The investment is hardened or "set" as concrete sets, the process sometimes being aided by drying out in a low temperature oven.
6. The pattern cluster is completely evacuated by the use of heat, leaving the desired cavities in a hardened investment or "invested flask."
7. The invested flask is brought to the desired casting temperature which can range from "chilled," or less than room temperature, to over 2000 F.
8. The casting is poured into the invested flask.
9. The investment is removed from the cast cluster, usually by the use of air hammers followed by tumbling or abrasive blasting.
10. The sprues are cut away, thus separating the individual cast parts.
11. Subsequent operations such as pickling, secondary machining and grinding, are performed if desired.

When parts are large enough, only one with its sprue (or sprues) is mounted in a single flask.

More detailed descriptions of the individual steps will appear later in this manual.

Economics of Precision Casting

Companies considering the purchase of parts made on contract by this process, or planning the installation of the process in their shops, should find the weights, dimensions and tolerances of the parts in question and then arrive at cost and quality comparisons.

The bulk of the cost of the process is in the preparation of the invested flask and getting the finished investment to the casting process.

Shops which have had the longest experience find that it costs (on the average) from $8.00 to $20.00 to bring an invested flask to the casting point. Exact cost figures depend upon the metal to be cast, the accuracies needed, the sizes needed, contours of the parts, and the burden which the shop in question customarily adds, in that order.

Any generalized statements on costs are so studded with "but ifs" as to resemble porcupines. With that hazard understood, some average cost conditions found in the industry can be handled.

Invested flasks of the most common sizes hold from 4 to 6 lb. of metal, about 1/5 of which is sprues and other waste. Flasks of larger capacities are used occasionally and many of them are under experiment. The waste metal can run as high as 60%, depending upon the casting contour, the flask size and the shop methods; described here are results of many shops.

Invested flasks at the casting point cost less for nonferrous than for ferrous metals.

A fair typical cost for such an invested flask for nonferrous metals would be from $8.00 to $10.00 which works out to approximately $2.00 for each pound of finished castings.

A fair typical cost for such an invested flask for ferrous metals would be from $12.00 to $15.00, or about $3.00 per lb. of finished castings.

To these figures must be added the cost of the metal to be cast, and the costs of knocking out, removing sprues, cleaning up the castings, and of costs of any secondary machining operations.

The invested flask is a tool, and a tool which cannot be used a second time. With its cost so high there seldom is much point in casting low cost metals such as gray iron. The added costs of metals of higher strengths and corrosion resistances make very little difference, percentage wise, in the overall costs of the finished castings.

Lowest costs attainable for any sizes of completely finished castings appear to be about $0.25 per casting for some nonferrous and $0.30 per casting for some ferrous castings.

Lowest economical production runs depend upon accuracies and upon contours.

When accuracies to the order of ± 0.008 in. are sufficient, the production of a single piece by the precision investment casting method often is economical, provided that the piece has no contours so unusual as to force the shop to spend a great deal of money upon experiments.

When accuracies are closer than this, production runs must go up to pay for added tool costs and for closer supervision of operations.

Unusual contours on the finished pieces can force a shop to spend as much as $1,000 on experimentation before the molds are right and the cast pieces are "coming right" or are being produced with minimum spoilage and rejections. Fortunately, the established shops now have made parts of so many varying contours that only a very rare piece would be unfamiliar to them. As experimental costs go up, production runs must go up to absorb them. Tricky contours can also involve high tooling costs.

Runs from 1 to 10,000 Pieces

Minimum economical production runs, then, can be all the way from 1 to 10,000 pieces, with the typical minimum for machine parts appearing to be within the 500 to 2000 range.

There is no apparent limit on maximum production runs. When con-

tours are intricate, tolerances are exact, and especially when parts are to be made of metals which are virtually impossible to machine or grind to the desired accuracies, production runs of millions of duplicate parts have been economical by this process.

Many other parts have been economical by this process only when required in smaller quantities than would justify fully automatic machine tool setups. On such parts the maximum production runs assigned to precision investment casting commonly range from 2,000 to 10,000 pieces. When it has been the shop custom to solder, weld, or otherwise fasten one fully finished part to another in the fabrication of a completed part, then the two or more individual pieces can be cast as a single piece having structural properties superior to the previous assembly. In these cases the production runs may need to reach the hundreds of thousands before the economies of machine tools and of assembling can overtake those of precision investment casting.

Engineers who like to calculate everything in terms of man hours and to base their costs estimates accordingly will find interesting the fact that in one "average" shop, over a period of years, average production was 1000 finished castings for each 10 employees per day, or 100 per man-day. Production was higher, of course, on castings so small that 20 or more could be clustered in a single investment, and lower on castings so large that only one could be placed in an investment. Costs in this shop were in line with those of several others which divulged costs figures, that is, to produce nonferrous castings for slightly over $2.00 an average pound exclusive of the costs of the metals, and to produce ferrous castings at slightly over $3.00 a pound on the same basis.

Observations and figures in several shops indicate that an original investment of $20,000 to $25,000 for equipment, value of floor space, original stock of raw materials and supplies and original operating capital, would be necessary if a new shop intended to "start from scratch" and produce a volume ranging from $100,000 to $125,000 a year at a net profit of from 10% to 15%, sales prices for the castings being taken at the 1945 figures, and metals cast being those ordinarily called "common nonferrous" and "alloy steels" and not the precious metals which would raise the sales prices and the business volume calculations much higher.

A production unit of this size can be set up in 1000 sq. ft. of floor space. It involves a minimum of materials handling equipment and of other mechanization. Units of much higher capacities can greatly reduce their overall production costs by mechanization. In fact, the savings in costs of intricate-accurate parts made by this process and the opportunities offered to machine parts designers have been so great that shop mechanization has largely been overlooked in the rush to get the process into operation.

Competition is likely to bring more mechanization in the near future. Capital equipment investments seems likely to rise to at least $5,000 per employee instead of the $2,500 which now seems to be common. There are a few high production shops right now in which the capital investment is well above the $5,000 per employee figure, and these shops are proving themselves able to take business of some kinds at prices which the lower investment per man shops are turning down.

The exact effects of increased mechanization are not fully known. Too few of the really big shops have reached full production. A shop having more than $200,000 worth of buildings and equipment has a projected capacity of $300 a year for each $1.00 of investment, based upon solid 50-week work years and upon receiving 1945 prices for the output. But this shop has yet to work a full year to prove what it can do under actual operating conditions.

Companies intending to enter this field should study the patent picture carefully. More than 20 patents on the process itself and upon various phases of it have been issued, and as many more appear to be pending. Very few of these patents have been in the law courts to an extent sufficient to make their validity legally clear. Royalty and license fees, when any are charged, seem to run about 5% of the fair value of goods produced under any one patent or group of patents.

The trained parts production engineer will recognize that these averaged and generalized figures, and others which will appear in this manual, are adequate only to show the general field in which precision investment casting belongs. They are no substitute whatever for making inquiries direct to the equipment makers, supply houses, patentees and manufacturing contractors which serve this field. The use of such generalizations can be justified only by the fact that this process is so new to industry in general that not more than one in one thousand manufacturing plants, machine shops and foundries which could make profitable use of it appear to know enough about it to form opinions as to where it can profit them and where it cannot. A year or two from now, when the American Foundrymen's Association has finished a study which is just getting under way, more accurate general figures regarding precision investment casting will be available.

Design Factors in Precision Investment Castings

Precision investment castings cost so much to produce that they usually are bought, sold and calculated on a "per piece" or "per hundred or per thousand pieces" basis rather than on the per pound basis that usually applies to castings. Nevertheless, in designing them it is necessary to think in terms of pounds or ounces of metal vs. dimensions, structural design, tolerances, contours, surface smoothness or finish, and alloys used.

The best time to think about precision investment casting as a way to produce a given piece is before that piece is on the drafting board. When it is in the planning stage, the part can be modified to fit whatever production method is selected for it, and changes leading to reductions in its cost and to improvements in its performance are easiest to make.

Precision investment casting shares this situation with screw machine op-

This supercharger impeller represents one of the largest precision castings made on a production basis. It weighs approximately 25 lb. and has an overall length of about 16 in. The part is made of both magnesium and aluminum alloy. (Courtesy: Arocast Corp.)

erations, stamping, die casting, forging and every other metal forming or fabrication method. When a piece is originally planned for production on the screw machine, the engineer will plan to remove as little metal by machining as he can and to let the various sections of the piece come as heavy as they may; he will establish some tolerances which are not necessary to the final functioning of the piece but are needed for setting up the piece in lathes or other machine tools for secondary operations; he will estimate stresses and strains in terms of the directional differences in strength commonly found in bar stock and establish some of his sections and contours accordingly; he will select the most machinable alloy he can and will design sections heavy enough to compensate for any loss of strength in the alloy which may accompany its improvement in machinability. When he gets through he has sections, tolerances and contours ideal for the screw machine but not good for stamping, forging or precision investment casting, each of which has its own design factors.

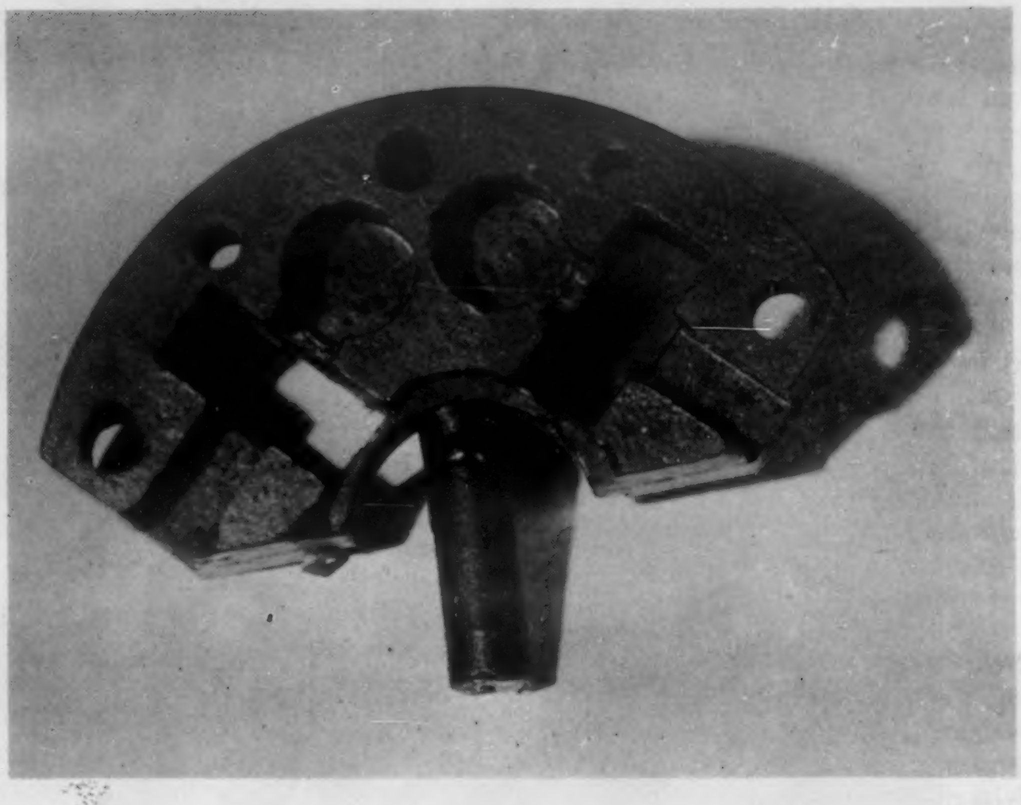
Precision investment casting design is almost opposite to that of screw machine parts.

Precision investment design avoids heavy sections. It does not need them either to avoid the machining-away of metals or to compensate for directional strength in the alloy or to compensate for the sacrificing of strength to procure machinability. It is penalized to some extent by heavy sections in that a light section adjacent to a heavy one can be a casting problem.

Likewise, this process eliminates many secondary machining operations and many hardening and subsequent grinding operations. Therefore, it avoids the need for holding many dimensions to close tolerances; also the need for making dimensions oversize to provide for heat treatment warpage and to leave grinding stock.

Many of the most exacting machining and stamping operations are to permit subsequent joining of parts. Typical of these are threading, drilling and tapping, tapering, grinding to the close limits needed for force or shrink fits, finishing to close dimensions and surfaces for welding or brazing. Extra thick sections can be provided to have enough strength at the fastening. Precision investment casting can avoid much machining cost necessary to provide for assembly and much of the assembly operation cost, by casting two or more parts integrally. The assembly may need redesign to fit it to this process. The process may permit redesign which will improve abilities of the assembly to do the job for which it was designed.

For heavy sections precision investment casting design prefers to substitute thin walls with ribs, fillets and other strengthening design members. When extra strength or stiffness is required, precision investment casting prefers to use stronger alloys; it can do so at little extra metal cost and sometimes at actual saving because it wastes almost nothing to scrap and because of the high strength-for-size ratio of its designs. When abrasion resistance, corrosion resistance and similar properties are wanted, this process prefers to obtain these also by the use of superior metals.



To produce a part on which angles are in close alignment, a shroud was provided on the wax pattern. After the casting is poured, the shroud is cut off and an accurate part, with all openings having parallel sides, remains.

be overwhelming before he can go through the shop engineering and sales engineering costs of quoting with any reasonable hope of getting the business.

Frequently the designer can take his dream designs, the ones he passed up because they were too costly to fabricate, and send them to the precision investment contractor for production. He will have to do more than dust off the blueprints and mail them. He will have to make changes leading to higher values with lower costs. But in thousands of instances this process has given him the parts he despaired of getting.

The functional design of every machine part is a combination of compromises. Accuracies are sacrificed to keep within permissible costs, contours and weights to keep within strengths of materials, corrosion and abrasion resistance to avoid production difficulties, and so on. Compromises appear in everything from the simple bolt and nut to the most complex intermittent or varied motion assembly. Precision investment casting can modify or eliminate many of the most bothersome compromises and thus remove shackles from designers. But when screw machine operation or other production means are yielding satisfactory parts at low cost, when some other production means finds a part highly suited to it, precision investment casting is not likely to cut the cost on that part. This process has its own limitations, its own compromises.

One highly successful designer of parts to be made by the precision investment casting method follows this working sequence:

1. Study the complete design of the machine for which the parts are to be made, and gang into single castings all of the present small parts which now are fastened together by various means but reasonably could be combined into a single casting. This can mean that only one present part will be replaced by a single casting, or it can mean that as many as four or even more parts which now are made individually and then assembled together will be redesigned into a single integral casting.
2. Having made a drawing of these present parts assembled together, blow that drawing up until it is 10 or 20 times its true size.
3. Estimate the stresses, strains and other service factors of the assembly, and similarly increase them until their figures are in proportion to the blown up drawing. This usually means increasing the figures to exactly the same extent that you increased the size of the drawing, but the engineer must use his judgment and common sense.
4. Now proceed as if the blown up drawing were the true size and you were going to design it into the strongest but lightest weight and thinnest section static casting adequate for its service factors. Use ribs, fillets and all other strengthening design members in it.
5. Repeat step 4 but modify the design to suit the strength factors of the strongest obtainable alloys, or the corrosion and abrasion resistance factors of the most resistant metals, in accordance with the service conditions which the part is to meet. Pay no attention to the machinabilities of the metals; this process eliminates nearly all machining operations. Pay little attention to the comparative costs of various alloys, excepting, of course, as you would avoid substituting platinum for stainless steel; this process wastes so little metal to scrap that the effects of alloys costs upon final cost are slight in comparison to the savings of pounds of material by taking advantage of metal-strengths to reduce thicknesses of sections.
6. Reduce the final blown-up drawing to the actual size, recheck all strength and service factors, make sure that the casting is within the limitations of the process as shown in various parts of this manual. If found to be outside of those limitations, check up with contracting shops in the industry and find out whether or not they care to quote on it, or what design modifications they suggest. The process limita-

tions shown in this manual are only general and the industry is removing limitations from itself every day, nevertheless the most practical field for precision investment castings lies within the limitations shown here.

This method serves to take the precision investment casting design up into dimensional fields with which the average designer of castings is more familiar.

Size of Parts

The typical precision investment casting weighs more than 1 gram and less than 8 oz., has no section continuously thicker than 0.25 in. or thinner than 0.40 in., and has no dimension longer than 2 in. It is within this range that the process seems to have its widest general field of usefulness. Prices per finished piece or per pound of completed castings seem to be lowest in this range, all other factors such as material costs being equal.

The typical contracting shop seems to be set up to cast no dimension larger than 5 in., no weight of a single casting greater than 5 lb., and no section continuously thicker than 0.375 in. or thinner than 0.035 in. And to achieve a weight per casting of over 1 lb. or a section continuously thicker than 0.25 in., the general run of contracting shops would have to do a great deal of pilot plant experimenting.

When a section is not continuous in thickness but is in successive gradients of thickness—examples would be wedges, gear teeth, turbine blades—then it is practical to bring its thinnest edge down to 0.015 in. or even less.

Pieces of dimensions and weights far beyond these general limits are being cast by the precision investment method on a commercial basis. They are more costly on a per pound basis, but they justify themselves by being less costly to produce by this method than by any other or even by the fact that this method is the only known way to make them of the desired metals at commercially practical prices.

The extremes of commercial sizes and weights seen during the preparation of this manual were:

Thinnest continuous section: 0.005 in. on a piece measuring 0.25 in. long by 0.125 in. wide.
Thickest continuous section: 5 in.
Longest dimension of any section: 18 in.
Heaviest weight of a single casting: 35 lb. of stainless steel.
Thinnest edge on a noncontinuous section: 0.005 in.

It should not be assumed that these are the extremes of sizes that anybody is casting anywhere. Many shops are keeping secret their experimental and even their extreme commercial developments.

Relation of Section Thinness to Dimensions

As stunts, shops have captured cockroaches, invested them in investment materials without duplicating them in wax, led wax sprues to them, baked the invested flasks to remove the wax and as much of the insect body as would burn away, poured in bronze by centrifugal casting methods, and come out with bronze cockroaches mounted on sprues. Flies and spiders have been similarly cast. All the fine details of the wings of the fly, the legs of the cockroach and even some of the hairs of the spider have been brought out. This can be done because the body of the insect, together with the sprue, forms a heavy section of metal from which the thin sections can draw.

Inordinately thin sections seem to need to be connected to thicker sections, which means that they either must be integral with thick sections of the parts being made or else that they can be produced only by disproportionate weights of sprues to useful parts.

There also is an unexplored relationship between the thickness of the section and the width as compared to the length. Thus a "hair" or wire seems to be castable in thicknesses as little as 0.002-in. and length of over 2 in., the exact length being unknown since the information was gleaned when 0.002-in. vent holes were put in experimental invested flasks and the cast metal formed the wires by filling those holes.

Sections 0.25 in. long by 0.125 in. wide have been cast 0.005 in. thick.
Sections 0.75 in. long by 0.50 in. wide have been cast 0.020 in. thick.
Sections 1 in. long by 1 in. wide have been cast 0.025 in. thick.
Sections 4 in. long by 4 in. wide have been cast 0.030 in. thick.
Sections 0.040 in. thick seem to be castable to any length and width that the invested flasks will take.

It is unwise, unless absolutely necessary, to design any section continuously less than 0.030 in. thick, and 0.040 in. is greatly preferable. Thin sections usually occur in designs which have curved contours, have ribs, or have other means of stiffening the pieces.

Threads, Holes, Contours

Threads, either internal or external, of any sizes from those used on instrument and watch screws to those large enough to be 0.25 in. or more thick at the roots can be produced. Very seldom are their accuracies closer than number 2 fit.

Contours of threads, of gear teeth and of similar shapes are easier to produce than it is to hold their accuracies. The subject of accuracy is discussed in another part of this manual. Any known thread contours can be produced by this method, and so far as true and accurate contour of a thread form is concerned, the process is satisfactorily accurate for the great majority of purposes. However, when long threaded sections are needed there can be problems of accuracy of pitch. The process is generally, but not completely, limited to accuracies to the order of ± 0.003 in. per in. of dimension, which is more tolerance than certain thread pitches can stand on some long threaded sections, since the effects of pitch inaccuracies tend to be cumulative over long threaded sections.

As is the case with most applications which need closer accuracies than are normal for precision casting, threads which are highly accurate in pitch over long threaded sections can be had if their extra costs are justified. Those extra costs are caused (1) by higher tool costs for the production of the expendable pattern, (2) by high rejection rates in the inspections of the finished parts, and (3) by the costs of extra close control of all steps of the process.

Internal threads are likely to be "cleaner" than external ones in that the internal threads in the expendable patterns usually are formed over threaded cores which chase the wax threads as the cores are backed out, and in that internal threads so produced have no parting lines. External threads are not chased or cleaned up unless absolutely necessary, and commonly will show two or more faint vestiges of parting lines at the points where the expendable pattern molds or dies separate to permit removal of the patterns. The number of parting lines depends upon the number of sections in which the die or mold is made. Seldom are these parting lines visible on finished castings unless the

observer looks carefully for them; almost never do they affect the performance of the threaded section. The parting lines can be cleaned up or eliminated if necessary.

Holes, recesses and chambers of large diameters can be of any sizes which will leave adequate thickness of sections in the walls of the piece. They can be of any shape. Chambers can have entrances smaller than their main diameters, and these entrances can be led to the chambers from any angle or any part of the surface of the casting.

Holes can be round, square or of any desired shape, and can follow curved paths, angular paths or tortuous paths as well as straight paths, as desired.

Small holes down to 0.050 in. dia. can be cored into castings by most shops. Even smaller diameters can be produced, dependent upon their lengths, their locations, their depths, and whether or not they are to be open at both ends so the tiny rods of investment, which will keep them open as the castings are poured, will be supported at both ends.

Contours vs. Accuracies

Extremely severe undercuts can be produced, but they usually require higher costs in molding expendable patterns, knocking out the investment after the casting has been made, and in final inspection of the parts.

There seems to be no limit to the fineness of surface detail that can be picked up; details as fine as the engine turnings on the backs of old fashioned pocket watches will come out perfectly. Sections of extremely fine detail can be contiguous to sections having highly polished surfaces or can be at the bottoms of recesses which cause thin walled sections to be next to heavy walled sections.

So far as details of contours are concerned, then, there seem to be very few limitations on the shapes and finishes that the process can produce. Dimensional accuracies of these contours are another matter. Accuracies should not be specified any closer than functions of the part demand. Too many designers run their precision castings costs too high merely because they are accustomed to designing for stamping or for other processes which either must produce to certain accuracies or not produce the contours at all. As one highly experienced designer of precision investment casting parts expressed it:

"Don't ask us to do stunts and don't aim at impossibilities. Aim to save money and to improve your product by this process and you will hit what you aim at."

Hollow Parts

Precision investment castings are made hollow to provide passages through which liquids or gases can flow, to reduce weights of parts, to provide convenient means of parts assembly, to give parts large exterior dimensions while avoiding the pattern and investment troubles of thick sections, to obtain dimensional accuracies which because of metal-shrinkage phenomena are sometimes easier to hold with thin sections than with thick ones, and to reduce the weight of high cost alloy used per casting. The change from solid sections where bulk is required to thin-walled hollow ones often is the hardest mental transition for the parts designer to make when he begins to work with precision investment castings.

Insofar as is practical hollow parts should have clear through passages having two or more openings of at least 0.25 in. widths or diameters. These passages do not have to go straight through, they can follow curved or angular paths, and they can vary in width or diameter and in cross-sectional shapes, as desired, at any points along their lengths. Their purposes are to provide the structural strength of two or more end supports for the core of investment about which the molten metal must flow in the pouring of the casting, to simplify the molding or forming of the expendable pattern, and to reduce the costs of knocking out the investment after the casting is poured.

Hollow castings can range from those which have holes clear through them to those which are completely closed shells with no openings at all.

Completely closed shells can be made by three methods which are in fairly common use, and perhaps by other methods.

The first method is used when there is no objection to leaving some investment material inside the shell. A piece of investment material the size and shape of the desired hollow is molded and allowed to set; this piece can have uninterrupted surfaces or it can have recesses for the purpose of providing strengthening ribs and other shapes inside the shell. The piece then is surrounded with a wall of expendable pattern material of the thickness desired in the shell and of the exterior shape desired and is invested with sprues and is cast in the regular way.

The second method provides a thin walled closed shell of a metal having a melting point equal to or higher than that of the alloy which is to be cast about it, a few tiny perforations being made in it to prevent its bursting from air pressure when the cast metal is poured around it. The expendable pattern material is formed about it as in the first method, but this step can be performed under vacuum to exhaust most of the air in the shell. The piece then is invested, sprued and cast in the regular way.

The third method is like the first except that openings are cored-in so the investment can be removed from the shell interior, these openings are closed later by welding or other means.

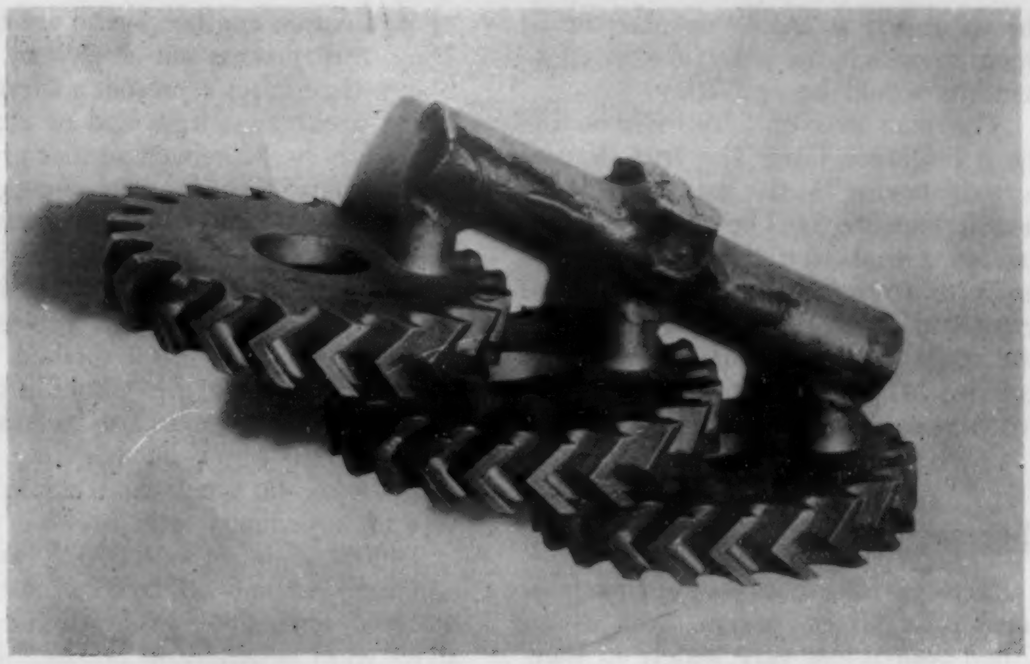
Accuracy

If asked to what accuracy he could produce by precision investment methods, an experienced contractor would be likely to ask in turn: "On what dimension or dimensions, of what size and shape of piece, made of what alloy, and in some instances, with what permissible sacrifice of alloy grain structure or of the strength of the part?—This slightly lowered strength to be found in some cases at the part section where the high accuracy is held and in other cases at other sections of the part."

Accuracy can be of several kinds or categories. In common with all methods of producing metal parts, precision investment casting does not achieve accuracy equally well in all categories.

1. *Dimensional* or "cross sectional" accuracy. Example: measuring directly or diametrically across a cylindrical section. Here the process is at its greatest dependability in accuracy.

2. *Parallel* accuracy of two sections which may or may not be in the same plane. Example: The two long sides of an H-shaped section are to be kept in true parallel. Here, dependent upon relative thicknesses of sections and other factors, the castings can be subject to run out troubles so they tend



Here is a view of a cluster of herringbone gears showing how they were grouped for economical casting. (Parts courtesy of Austenal Laboratories, Inc.)

to have concave shapes rather than the true straight sides of an H. On a U- or a Y-shaped section the open ends may tend to spread too far apart, or to do the opposite and bend inward, in either case destroying the true parallelism or angularity desired.

The producer has ways of dealing with these troubles and of bringing his parallel accuracies into line. Usually this requires development of methods by pilot plant operations which must be justified by higher prices or by higher production runs.

3. *Angular* accuracy. Example: a thin projection on a thick section is to be at an angle of exactly 30-deg. from the surface or plane of the thick section. As with parallel accuracy, there are likely to be run out troubles.

4. *Contour* accuracy, such as requiring that a surface be a true flat plane, or truly spherical, or to a true cam shape. This is easy to produce within limits when all sections of the piece as measured from that surface are of equal thicknesses. But when the surface is a continuation of thick and thin sections, there are likely to be run out troubles.

5. *Surface finish* accuracy. Polished surfaces can be secured on some metals, and the type of finish is highly controllable on all metals. But "super finish" accuracies which would be measured in millionths of an inch are not to be attempted in the present state of this art.

Surface finishes intended to give various decorative effects, and surfaces intended to give specified "skin depths" or skin effects for subsequent machining or grinding, can be supplied.

Cleanliness of surface, surfaces which are free of blow holes and like defects and which are pleasingly uniform in color and finish, are common to this process.

The confusing number of categories or kinds of accuracies, and the ways in which this process differs from other fabricating methods in almost automatically bringing accuracies within certain figures, has made precision investment castings producers wary of the whole subject of accuracy. The problem is not that of providing necessary accuracies but of meeting customer's specifications of unnecessary ones.

One example of what happens is a part which previously had been turned out on turret lathes. Precision investment casting would permit several features to be added to the part design and would reduce its cost as well. When the final blueprint came through it showed accuracies on some dimensions which were impractical for precision casting unless the process were to be carried on at much higher costs than the quotations had covered. Investigation showed that these were the accuracies to which a highly accurate turret lathe would automatically turn the part when making cuts which had no other purpose than to clean up the part and improve its appearance. Since the appearances of precision investment castings would be far better than needed and no cleaning up operations were necessary on them, these penalizing tolerances were eliminated.

In another case the customer supplied a master pattern which had been used for other forms of casting having about the same shrinkages as precision casting. He wanted the higher accuracies of precision investment casting and he specified accuracies as close as the process can deliver. Measurement of his master pattern showed it to be so inaccurate that castings made with its use could not even reach those ordinary to the process, let alone the extreme accuracies he had specified.

The best way out of the maze of accuracy questions is a full and frank discussion of parts designs and the reasons for accuracies with the contracting houses. Or, if a plant is making precision investment castings for its own use, much help can be had from the sales engineers of the supplies and equipment houses. These discussions will come down to specific accuracies on specific sections or areas of the parts. They result in reduced costs on improved parts.

For discussion of the accuracies that can be achieved, precision investment casters use reference points, reference lines or reference areas, and then specify tolerances and limits in thousandths of an in. per in. of distance from these.

If a micrometer were being used to measure the diameter of a cylinder, for example, then the anvil of the mike would be the reference point and the distance from the anvil to the spindle as closed on the piece would

be expressed as inches or parts of an inch to which the tolerance in thousandths would be applied.

The true axis of a cylinder would be a reference line. The true base of a part having a flat base would be a reference area. The allowable run out of a thin section which is at an angle to a reference line would not be expressed in degrees and minutes of the angle but in thousandths of an in. per in. of progress of the measuring instrument along the reference line.

Tolerances Possible

With all tolerances reduced to thousandths of an in. per in., well established contractors vary widely in their opinions as to what "as cast" accuracies of the process should be called common. They can be broken down into groups:

Group 1. Specifies ±0.004 to 0.005 in. per in. as the closest tolerance for most work. This works down to ±0.001 in. for dimensions of 0.25 in. or less as the finest tolerance to be held. For example, on a solid cylindrical area of 0.25 in. dia. the very closest tolerance would be ±0.001 in., for any smaller diameter the tolerance would be the same, if the diameter were increased to 0.50 in., the tolerance would be ±0.002 in., and so on.

Group 2. Specifies ±0.003 in. per in. and applies this in straight line to dimensions down to about 0.0015 in. for a dimension of 0.50 in. But from 0.50 in. downward the 0.0015 in. tolerance is constant to about 0.25 in. at which the tolerance reaches its low point of ±0.001 in. This group is by far the largest one.

Group 3. Specifies ±0.002 in. per in. does not like to go below ±0.001 in. on any dimension, but can get down to ±0.0005 in. on occasion.

Group 4. Specifies ±0.001 in. per in. Will get down to ±0.00025 in. on some sections in some alloys.

It should be made clear at this point that these are the tolerances specified by production engineers who are operating this process on a day by day basis—the figures represent a survey of actual production lines and of experimental shops. Moreover, similar groups of ordinary working accuracies, although not to the same tolerances, of course, would be found if a similar study were made of automatic screw machine operators, stampings producers, or any other fabrication method.

The average of the whole process would work out to "as-cut" tolerances of 0.003 to 0.004 in. per in., with ±0.001 in. on small dimensions the very finest ordinary tolerance, but with ±0.0005 in. or even 0.00025 in. attainable on some dimensions of parts made of some alloys. The nonferrous alloys seem generally to be castable to finer tolerances than the ferrous. No tolerance finer than ±0.002 in. should be demanded unless there is a compelling reason for it.

Comparisons of the ways in which these tolerances work out for various parts will suggest to the engineer the ways in which this process can fit his problems.

Example 1: A solid cylindrical piece 0.25 in. in diameter and 2-in. long threaded throughout its length. With its true axis taken as the reference line it could vary in straightness to the order of 0.001 in. per in. of length but these variations would be minor at any point; it would not take the form of an arc of a circle. Its diameter would be true to ±0.001 in. The thicknesses of individual threads at any points of their cross sections would be true to ±0.001 in. and probably would be much closer than that. The possible error in pitch over the length of the piece would be ±0.003 in. per in. or ±0.006 in. for the whole 2-in. length.

Example 2: A spur gear having a pitch diameter slightly over 1.0 in. The pitch diameter would be true to ±0.003 in. The concentricity would be measured with the bore or shaft center line as the reference line and would be ±0.0015 in. Thickness and contours of sections of individual teeth would be ±0.001 in. or closer.

Example 3: A tapered piece in the form of a right angle triangle having one leg 3.0 in. long, the other leg 1.0 in. long, the hypotenuse to serve as the taper. The point of this could be as thin as 0.015 in. or even 0.005 in., in either case ±0.001 in. The length could vary by ±0.009 in. and the height, if the taper were considered to be a slope, by ±0.003 in., so that combinations of those two variations could make significant differences in degree of taper, the importance of those differences depending upon the purposes for which the piece is made.

Example 4: A disk 5-in. in dia. such as might be used as the ball spacer or retainer for a flat raced ball thrust bearing. Perforations 1/16 in. dia. are cored into this disk to receive the balls. The perforations are arranged in rings or circles which are as concentric with the axis of the disk as the casting process will make them. The first ring is 1 in. in dia., and each successive ring is 1 in. larger in dia. The perforations at each ring are as close to ½ in. apart as measured along that ring as the process will make them.

The first ring, then, will have a radius of 0.50 in. and will be concentric with the axis of the disk to ±0.0015 in. The second ring will be concentric with that axis only within ±0.003 in. per in. of its radius. The rings can vary from being true circles by the same tolerances.

Nevertheless, each perforation no matter what its distance from the axis will have a diameter of 1/16 in. ±0.001 in., and the perforations will be equally spaced in their center to center distances as measured along the lines of their own rings to ±0.0015 in.

This being a circular disk, the laws of shrinkage would operate to produce true concentricity of all the rings if all operations were carried out perfectly.

It is conceivable that a contractor might make a mold having a cavity of perfectly circular periphery, keep the centers of all the inserts or bosses for the perforations on perfectly circular rings, keep the mold so all its parts are at constantly equal temperatures so expansion and contraction would throw no rings out of concentricity, inject the wax or other dispensable pattern material in such manner that there are no strains in it and it will shrink and set in perfectly circular form, carry out the sprueing, investing, burning-out and casting operations with equal accuracy, and thus come out with a casting in which all the rings of perforations are perfectly concentric. Such an operation is possible but improbable.

Example 5: A solid section is 2 in. long, 1 in. wide and ½ in. high. Its tolerances then are, respectively, ±0.006 in., 0.003 in. and 0.0015 in.

To save metal and avoid casting troubles of thick sections it is redesigned to be hollow but with a supporting wall down the middle; the design now resembles an open ended box with a lengthwise partition down its middle. The wall thicknesses can be true to ±0.001 in. although 0.0015 in. or 0.002 in. would be preferable. The tolerances on its length, width and height would be unchanged.

Selective Accuracy

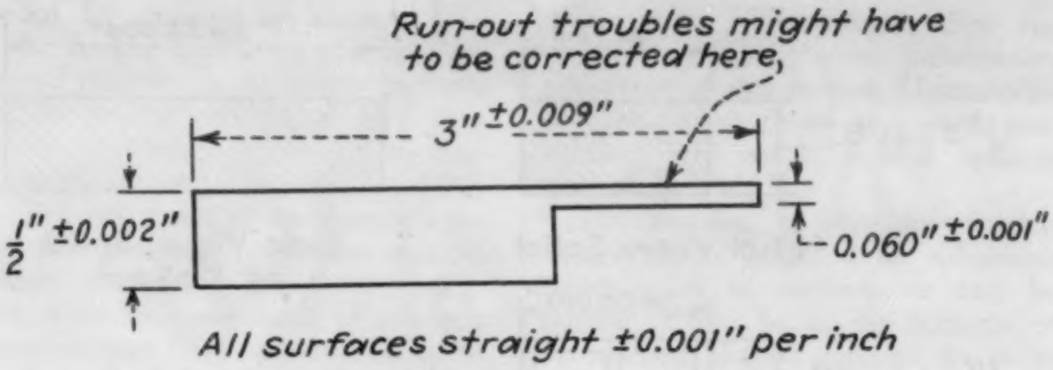
Example 6: A double ended stud having one end threaded RH and the other LH is to be 4 in. long. The threaded portions at each end are to be 3/8 in. in dia., and the threads are to extend 1/2 in. along them. This leaves a shank section 3 in. long between the threaded ends. The shank section is to be relieved so it is only 1/4 in. in dia.

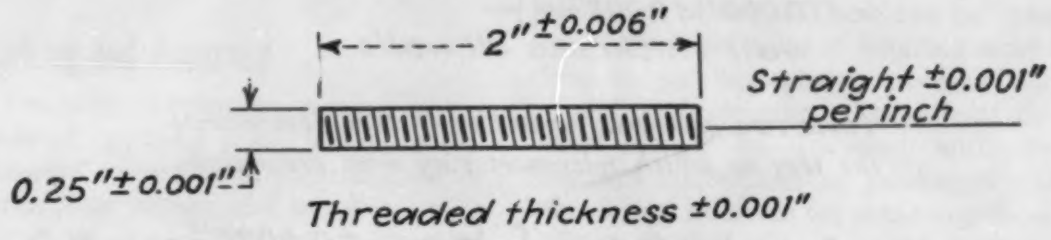
It is certain that the accuracy of the finished piece can be no greater than that of the dispensable pattern, the pattern accuracy no greater than that of the mold, and the mold generally no greater than that of the master pattern—although it is practical to some extent to "touch a mold up" for improvement in its accuracy.

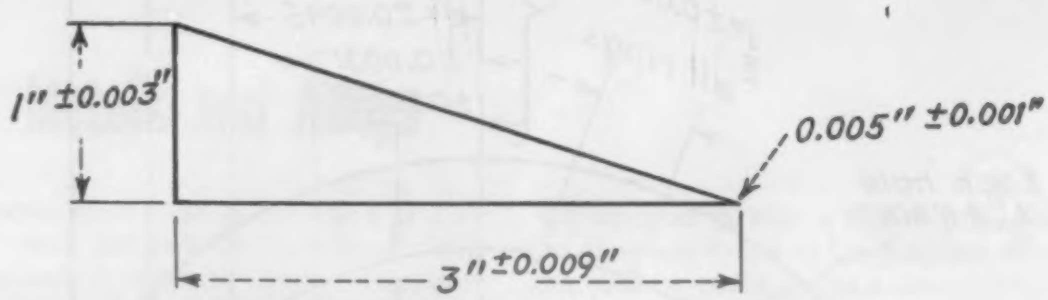
If the designer demands the highest accuracy in all sections of this piece then the master pattern will be costly to make and so will the mold. Moreover there will be high rejections of dispensable patterns due to inaccuracies in them, and high rejections of finished castings due to various errors along the production line.

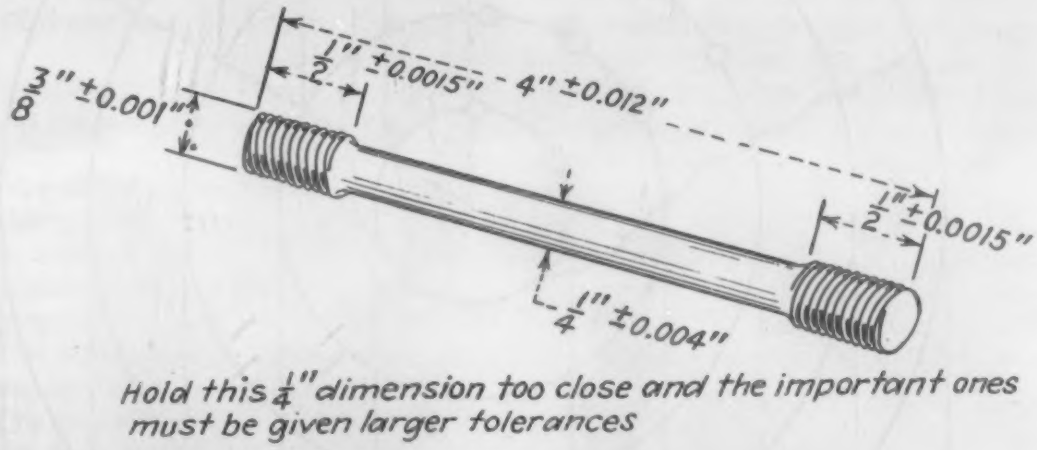
With every dimension highly accurate the diameters of the threaded ends will come to ±0.002 in. by average shop practice casting methods, the lengths of the threaded portions to ±0.002 in., and the diameter of the shank to ±0.001 in. or in some shops 0.0015 in.

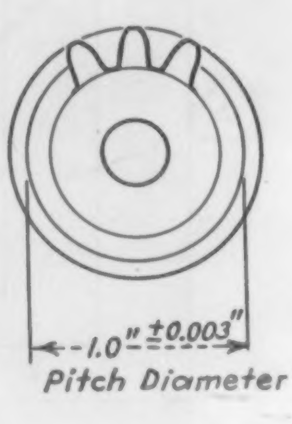
Let the designer permit the shank diameter to come to ±0.003 in., or even better, 0.004 in., and the contractor can concentrate on bringing those threaded ends to their highest accuracies. With equal cost figures the accuracy and finish of the master pattern and of the mold can be brought to the highest at those all important threaded ends. The wax or other dispensable pattern material can be injected at higher pressures at those end portions, and the setting of the pattern can be controlled so those ends will hold true. The invested flask can be



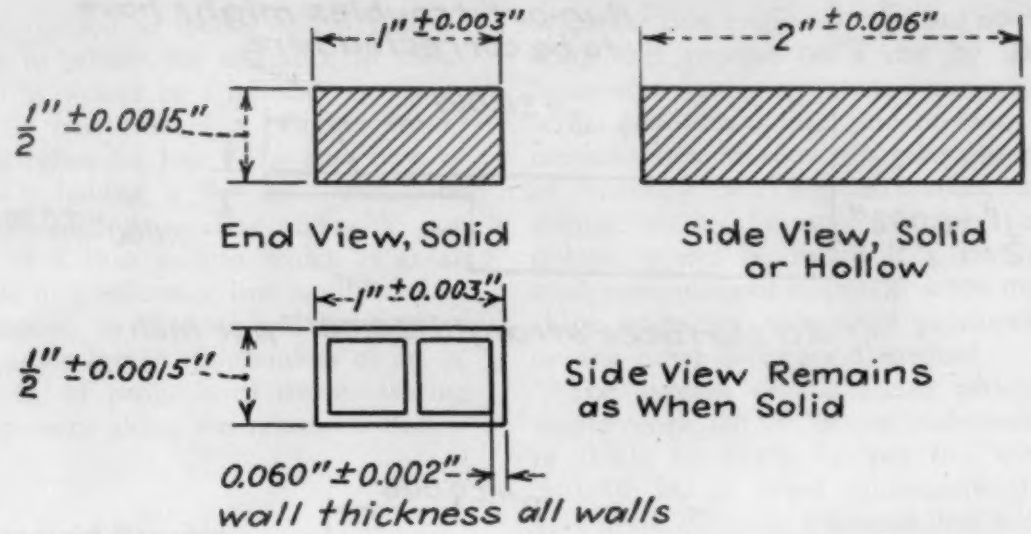




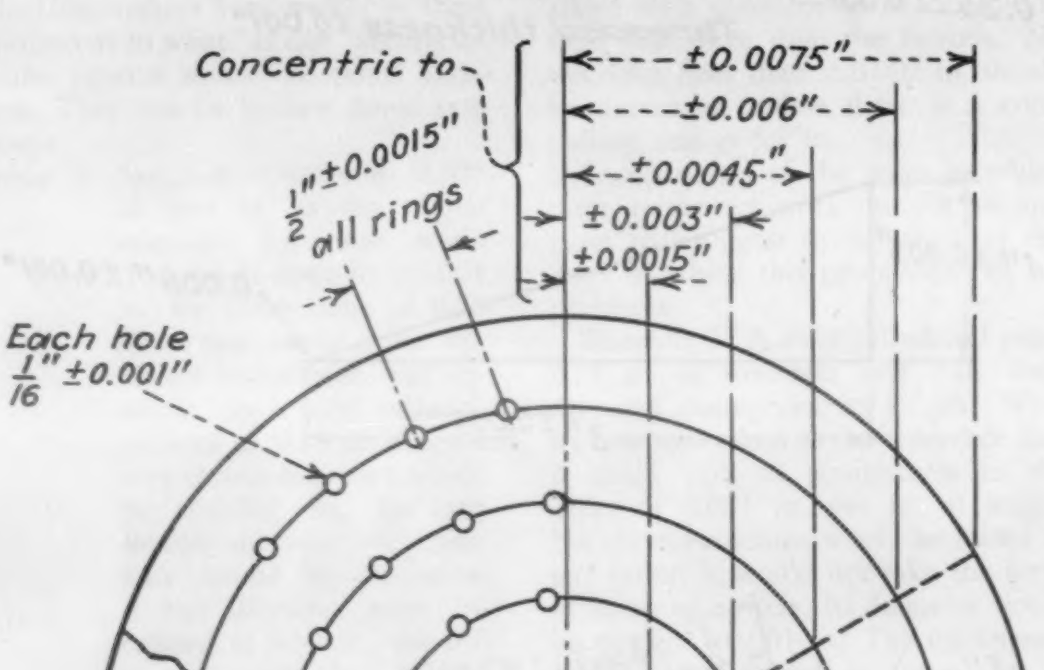




In precision casting some tolerances are more difficult to attain than others, thus the part to be produced must be studied and so designed as to provide tolerances that are within reasonable cost limits. These examples show how tolerances increase with increasing dimensions.



These two additional examples further demonstrate the way in which tolerances vary with dimensions.



designed for special sprueing so the casting of those ends will be to the highest accuracy. As a result, the threaded ends can be brought to ±0.001 in. on dia. and 0.0015 in. on length. The net cost will be less than as if the accuracy requirements had not been concentrated on those critical sections.

Secondary Operation Accuracy

Precision investment castings can be planned for completion by secondary machining and grinding operations. Sometimes this results in decreased costs for the finished parts, sometimes in increased accuracy, sometimes in both advantages. Many of the most successful contractors insist upon quoting upon finished parts without specifying the methods or operations by which they will make them.

Example 7: A cam weighing 1 oz. had to have a 0.25 in. hole in the off-center position through which its shaft would pass. If this hole were to be cored in, the wax patterns would have to be placed in the investment in positions oblique to the axis of the flask in order to prevent any entrapment of air in the holes. Because of the contours of this particular piece there was no way to achieve this oblique position while avoiding air entrapment anywhere and get more than 32 pieces into an invested flask. At a $15.00 cost for an invested flask, this meant about $0.50 per casting exclusive of metals cost and of finishing operations.

If this hole were not cored in, the air entrapment problems could be solved while getting 60 pieces into a flask. This would mean $0.25 per casting, or if the costs for clustering and sprueing went up a little, then perhaps $0.27 per casting. Drilling the holes would cost less than $0.05 per casting. By drilling the holes instead of coring them in, then, there would be a clear saving of over $0.15 per casting.

Example 8: A piece of a shape resembling a shaft key was 4 in. long by about 3/8 in. sq. Tolerances natural to the process would bring the length of this to ±0.012 in. and the width and height to ±0.002 in. Tolerances needed were ±0.002 in. on the length, 0.002 in. on the width and 0.001 in. on the height.

The piece was to be precision cast because it was made of materials very difficult to machine. By outright "as-cast" precision investment casting

methods those 0.002-in. tolerances could be had on the length only by selecting from the production the pieces which accidentally came within them; this would mean a scrap loss of at least 80% on unlucky days. The 0.001-in. tolerance could be held, but only at the expense of high cost casting methods.

The piece was sprued in such a manner that the metal would enter at one end. This sprue area would have to be ground to clean up the casting. With natural tolerances preserved the master pattern was made long enough so the limits would be +0.024 in. —0.000 in.; there always would be grinding stock at the end. Grinding was done in a fixture which brought the length well within the allowed ±0.002 in. and at only minutely greater grinding cost than would be needed for cleaning up alone.

The height dimension also was increased slightly on the master pattern, and on the casting, was ground in a fixture. This was less costly than casting to the extreme tolerance of ±0.001 in. The net result of combining casting and grinding operations was to achieve completely satisfactory accuracy, with the piece made of stronger materials than were economically feasible by any other production method, and with the piece made at less net cost than previous methods had yielded.

Marking and Accuracy

Precision investment casting is capable of applying trade marks, manufacturers' names, code identification of parts, alloy names and numbers, with minimum or no increases in costs or decreases in parts strengths. Few engineers are taking even rudimentary advantage of this feature. Merchandising advantages could be gained, production and stock control systems simplified.

The lettering or the identification design can be indented for minimum interruption of surface, or can be bossed, or can be at the bottoms of ornamental shaped recesses so as to get bold bossed lettering with minimum interruption of surface. But not all of these methods are equally feasible on all castings. There can be cases in which some styles of lettering would lead to air entrapment troubles and would increase costs. The effects desired should be discussed with the castings contractors or producers and the design methods for achieving those effects worked out.

Metals and Alloys

The factors which sell precision investment castings might be summed up in the three words: Alloys, intricacies, accuracies.

The process leans heavily upon the fact that nearly any alloys which can be cast at all can be cast by the precision investment method. This permits parts to be made of much stronger alloys than are practical for other production methods, and of alloys more resistant to abrasion and corrosion.

Often the part can be made lighter in weight or smaller in size by the use of these more durable alloys. Here the intricacies and accuracies to which the process can produce contours is important. The same redesign which saves weight and size can improve functional performance.

Precision investment casting almost always wastes less metal to scrap than any other process by which a given part can be made. When the alloy is of such kind that sprues and gates can be remelted and recast, the process wastes almost nothing. Since the amount of metal needed to produce a part by any process must include the metal wasted to scrap, it follows that this process uses fewer pounds of high cost metals per thousand finished parts. Also, its metal costs per part are exceedingly low, and that it often can use a "high cost" alloy where another process would use a "low cost" one at the same net cost for metals. Indeed, precision investment casting often substitutes high cost high alloy metals at lower net costs for metals.

One of the recent developments in precision casting is the successful casting of magnesium by this method.

Castabilities

Some alloys are more easily castable by this process than others. Surprisingly, some of the most easily castable are higher in their physical and chemical properties than some that are difficult to cast. Stainless steels, for instance, are far more castable than gray iron by this process.

The parts designer, therefore, should inform the contractor or his own casting set-up as to what qualities he wants in the piece and then arrive at a suitable alloy by discussion and agreement.

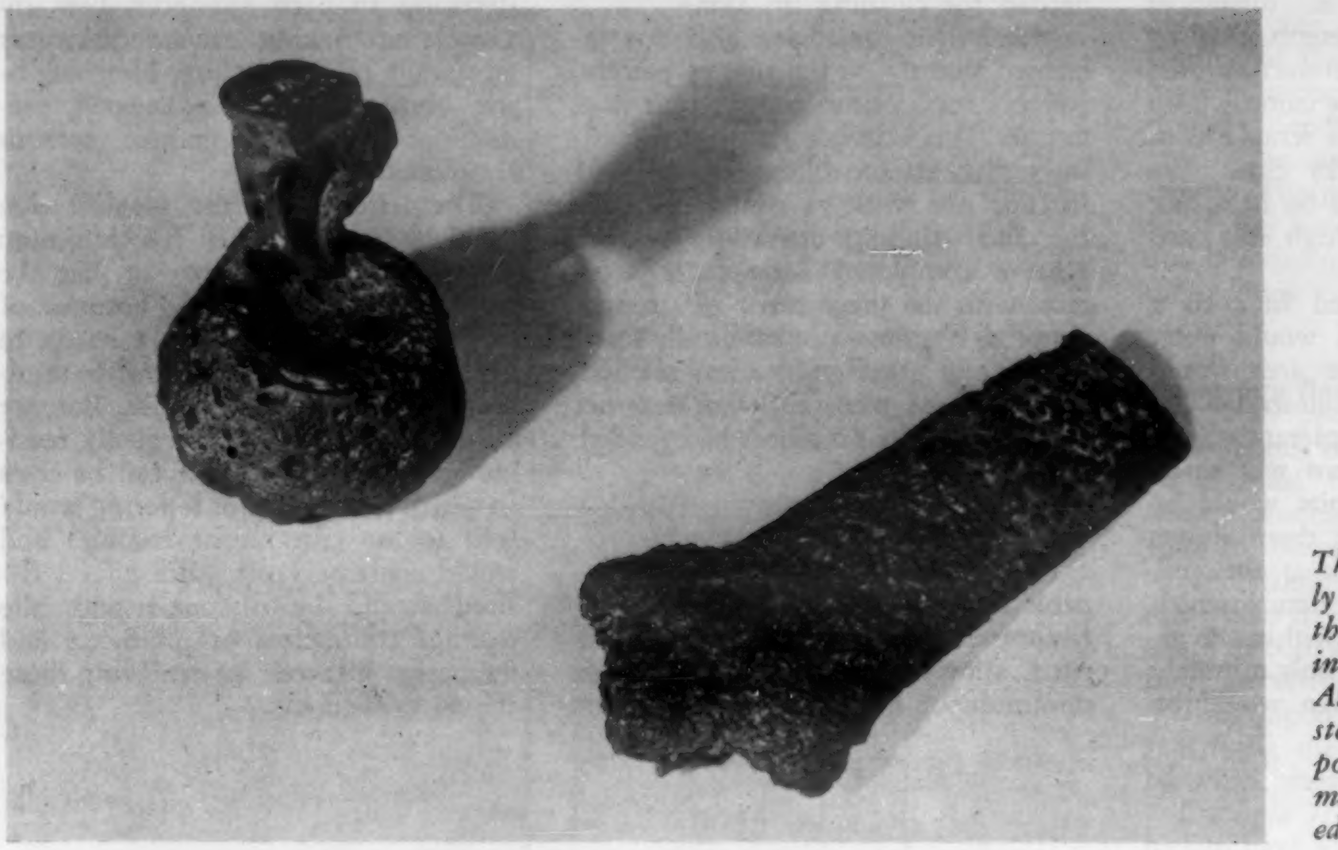
Insistence upon having the same metallurgical specification as in an alloy intended to be fabricated by machining, stamping or forging, can have two bad results. It can run the precision investment casting costs and prices up by increasing the costs for invested flasks, the experimental or pilot plant costs, the costs to cast, and the costs of rejections. It can result in the designer paying a higher price for an alloy less suited to his purposes than the one he could get at a lower price.

Gray iron vs. steel is a case in point. When gray iron is actually superior for the part in question, or when it is desirable to run the carbon content even higher than the gray iron range, then these metals can be cast and plenty of them have been cast. Statements that gray iron casting is something that the industry hopes to achieve are out of date. When steel of 1020 analysis and up can be substituted for the gray iron with equal or better qualities in the part, then the steel parts usually cost less than the gray iron if cast by this process.

Ideal Specifications

For the engineer who wants to experiment with alloys for this process, one engineer laid down a list of the qualities that the ideal alloy should have. They are:

1. Suitability for the purpose of the part.
2. Suitability for secondary operations if any are to be performed on the part.
3. High fluidity to follow the intricate passages in the invested flask.
4. Sharp fluidity; narrowest mushy range.



These castings are obviously imperfect. The piece at the left resulted from dirt in the investment material. At the right is a stainless steel casting which was poured into an investment made of a material intended for nonferrous use.

5. Non-critical melting point.
6. Non-segregating, non-separating.
7. Low shrinkage characteristics.
8. Cost of metal is important, but within common sense limits, this cost comes last.

With the exception of No. 1, any or all of these points can be violated and satisfactory castings be made at satisfactory prices. To the extent that any are violated the overall cost of the process is likely to rise, with much depending upon whether the part in question has any sharp and accurate contours such as threads, or any extremely thin sections projecting from thick ones, or any such features as large numbers of cored-in holes about which the metal must be made to flow.

There are dozens of other points which can come up occasionally. For example, a part design may include a recess so deep and large and with so small an entrance that only a thin shell of metal is left, or a hollow part may have interior members so thin and poorly supported that they easily could be broken off. In such cases the removal of the hardened investment material from the finished casting without breaking those weak sections can be a problem unless an alloy of very high strength is selected.

Nonferrous vs. Ferrous

Most nonferrous metals can be cast in investment materials which use plaster of Paris as a binder. Ferrous metals cannot, since this plaster breaks down at their casting temperatures and attacks them chemically.

The plaster makes such a smooth, dependable, workable binder that almost all casters prefer to use it when they can. However, it has to be kept out of ferrous investments since tiny amounts of plaster in them can ruin the castings.

To keep investment materials from being mixed, and for other reasons having to do with production techniques, nonferrous and ferrous castings almost never are sent down the same production line. The line is set up for one or the other, not for both.

This condition within the industry should not be construed to mean that a contractor or producer who has only one production line or setup should never be awarded contracts to produce both nonferrous and ferrous castings.

Using the same line for both types is a production control problem which can be solved, any damage done to ferrous castings by the use of investment materials intended for nonferrous metals is likely to be plainly visible so the castings will be rejected. The caster should be judged by his product and not by his production methods.

Several supplies makers have universal investments, suitable for ferrous and nonferrous castings alike, either on the market or almost ready to be marketed. When the use of these becomes more general, differences between ferrous and nonferrous production lines will be reduced.

As the situation stands today, the average shop specializes on nonferrous or else on ferrous castings, with the nonferrous shops in the majority since nonferrous casting by this process was well developed before ferrous became common.

Special Effects in Metals

Precision investment casting can produce strength and grain structure effects in metals which are difficult to obtain by other methods. The purist would argue, of course, that these effects are produced by the casting machine and could be had by casting into molds other than the precision investments which are the characteristic feature of this process; therefore, they are not precision investment casting effects in the strict sense of the expression. The answer is that pieces of the size, accuracy and contour suitable for this process seldom are cast by other methods; from that point on we will leave the matter to be taken up in a bull session somewhere.

There are strength control factors for which precision investment casting

is less adaptable than other production methods. Directional strength is one of these. Some directional strength can be imparted by some of the casting methods. If, for example, either centrifugal casting machines or high direct pressure machines are used, the sprues are long, and means are provided by which the molten metal rushes down the sprue with considerable initial velocity rather than with the usual low initial velocity followed by steadily increasing increments of pressure, then with some alloys the directional strengths of the castings will be least in directions which are in straight lines with the paths of the sprues and significantly greater in other directions. The exact figures on these differences were not released for the purposes of this manual, but in no case do they approach those obtainable by rolling, drawing, stamping or forging.

This fact can be of advantage when the designer wants metal shapes which are difficult to roll or draw, or shapes made of metals too hard to roll economically, or too prône to work harden in repeated passages beneath the rolls or through the dies.

Special bronze and other alloy bars have been precision cast in such manner as to give them some initial directional strength, then have been rolled to final sizes and directional strengths, and finally fabricated in automatic screw machines.

Channel shapes, U-, H-, X-, Z-, and V-shapes and others which ordinarily would be rolled or drawn from round or square bars but which are wanted in short pieces and of alloys difficult to roll or draw, have been precision investment cast with some initial directional strength to the shape and size which they ordinarily would have after the fourth or fifth passage through the rolls or dies, then have been rolled or drawn to their final shapes and directional strengths.

Directional strength in the precision investment casting may, of course, be unnecessary and even undesirable when the casting is to be rolled or drawn. In these cases the castings can be made with the highest uniformities of strengths no matter in which direction strengths are measured.

These shapes often are best made by precision casting them to their final shapes and dimensions. This is especially true when they are to be made of extremely hard metals, for instance, some of the cobalt and the nickel alloys.

Bronze alloys in sections only about 0.060 in. thick have been precision cast to hardnesses of 575 to 580 Brinell and used as metal cutting tools.

In aluminum bronzes some of the aluminum can be caused to go to the surface and form a coating which is both beautiful and protective.

Lead in lead-bearing alloys can similarly be caused to go the surface and coat the entire piece, forming a coating which is useful for protection and for anti-frictional properties if the piece is to be used as a bearing or is to be rolled or drawn.

Different metallurgical qualities can be produced in gradients at different sections of the same piece, especially if the alloy includes metals of widely different specific gravities. In one experimental case a bar 5 in. long by 0.25 in. dia. was cast, then was cut apart at 1 in. internals and analyzed.

The alloy contained aluminum and copper. Measuring from the sprue where the centrifugal force on the piece was least to the other end of the bar where that force was greatest, the percentages of aluminum found along the bar were:

First inch	4.44% aluminum
Second inch	3.06% aluminum
Third inch	2.10% aluminum
Fourth inch	1.73% aluminum
Fifth inch	1.51% aluminum

Parts fabricators use a great many methods to get different physical characteristics such as hardness and resilience at different sections of parts. The abilities of precision investment casting to contribute to this have not been explored enough to be known even empirically. In this direction may lie some of the greatest opportunities of the process.

Several casters have been able to increase the tensile strengths of aluminum alloys. One raised an alloy similar to 350S-T from a former 32,000 psi. to 41,000 psi. Another raised a different alloy from its former 20,000 psi. to 38,800 psi. By carefully controlled casting methods the tensile of any alloy of any type which is likely to form internal oxides can be raised from 25 to 50%, the procedure being to eliminate the oxides.

Porosity can be controlled. One contractor uses 500-lb. casting pressures to eliminate interior porosities of castings and gets perfect soundness. Porosities of the types used to provide capillary action to raise lubricating oils in bearings metals, and of the types which permit gases to pass through the metals at very low pressures for filtering and for safety devices, can be produced at will.

Metallurgical Control

There seem to be two schools of thought regarding metallurgical control of this process.

One says: "Because we are melting in pounds and ounces instead of tons we are able to control our alloys much better. It is much easier than running a steel mill."

The other says: "If we only could melt our metals by the ton we could aim at average results and get much better alloys. It is much harder than running a steel mill."

The fact is that the contractors who are exercising close control under skilled metallurgists are controlling their specifications without much trouble. Shipments of such metals as stainless steels are analyzed as received from the mills, then carbon, nickel, chromium, etc., are added to yield parts which are held to very close analyses.

Ferrous Alloys

With gray iron being cast only rarely, the casters of ferrous alloys seem to be divided into two groups. One group will cast anything from 1020 up to the very highest alloys, but likes best to work with alloys which are at least in the stainless steel range of 12 chromium or over. The second group seldom will cast any alloy less than 12 chromium and likes the high chromiums, the high nickels and the cobalt alloys much better.

Many contractors have their own brand name alloys for various purposes and have developed their own techniques for handling them. Quite a few of these alloys were well known before this process came into commercial prominence, but some of them were specially developed for precision investment casting. Some of the most intensive research on precision investment methods, products and product designs is being done by metals producers who have been stymied in their marketing efforts by the difficulties of machining their alloys and who see in this new process a way to expand their sales.

The most generally used ferrous alloys seem to be the stainless steels. These flow so readily in the invested flasks that many a contractor finds his costs lowest with them and many a

parts buyer is getting the strength and the corrosion resistance of stainless merely because his contractor can cast these alloys so readily.

There seems to be little evidence that the stainless steels which are subject to carbide precipitation stay within the critical range long enough to incur this trouble. One contractor, however, insists upon having any stainless of the 18:8 family contain stabilizing columbium at the ratio of ten times as much columbium as carbon, and another heat treats all such stainless castings to insure against carbide precipitation.

Surface decarburization of some high carbon steels can occur during the casting and cooling. In some cases this does no harm, in others the castings must be heat treated for the desired physical properties and the carbon can be restored during heat treatment. In other cases the casting process is carried out under high vacuum or in inert gas atmospheres to avoid decarburization.

Castings can be quenched for heat treatment, to some degree, by plunging the invested flask with its load of castings into water while the metal is still at the proper quenching temperature. Since the investment material is a good insulator this is only successful with metals that need a comparatively slow quench.

Quenching while the newly poured castings still are hot will be more practical when some of the newly developed investment materials that pulverize easily and can be removed quickly have been worked out more thoroughly in shop practice. Even so, the casting which is quenched with part of the gate or sprue still attached will present more difficult cleaning-up problems than the unhardened one. Heat treatment usually is best performed after all other operations excepting some of the final grinding ones have been completed.

Very often the specifying of a steel which must be heat treated after casting and machining is a hangover from shop customs which were necessary before the abilities of precision investment casting to fabricate the extremely high strength alloys came into being.

Within wide limits the parts designer or buyer is best off if he specifies the strengths, the other physicals and the corrosion or abrasion resistances he wants, then leaves it up to the precision investment caster to produce them.

Plant Practice and Methods

The purchaser who desires to buy precision investment castings, and the manufacturer who wishes to install his own plant to make them, must consider that there are as many ways of setting up and operating a castings plant as any other production process.

These differences in plants stem from outright production philosophies. If, by comparison, stampings were being purchased, one plant would be found to make small and intricate ones to better advantage than its competitors, another would be better for automobile body and other large stampings, another would specialize on Monel and another on stainless steel and so on. Inevitably the precision investment casting field is being divided up into segments of its own. These segments are being decided largely by viewpoints which practitioners carry over from their previous employments and skills.

Practically all of the men in this business learned some other trade before they entered it. The industry contains almost no men who were "born and raised in the shop, cut their teeth on soft metal molds and made their own toys out of spent pattern wax."

There are viewpoints and practices common to all in the industry, and men of all viewpoints are learning and

These two parts demonstrate some of the design principles that are so important in precision casting. Notice the thin webbing on the piece at left which is provided for extra strength. Both pieces have openings all the way through. (Parts courtesy of Trifari, Krussman & Fishel, Inc.)

adapting from each other. Some of the differing viewpoints:

The Foundryman's Viewpoint

Several large foundries have entered the precision investment castings field. The first of them appear to be specialists in high alloy castings which have had their markets modified by machining and other fabricating difficulties. But the field is of interest to every foundry and thousands of foundries are likely to enter it.

The foundryman characteristically studies every part to find out which of his processes will best produce it. If it falls within the precision investment casting field then he makes a methods study of it to find out what contours and other features are best produced by casting, what ones by machining or other secondary operation, and what alloys will best lend themselves to the functions of the part and to the operations balance for making it. He installs special machine shops for secondary operations.

He prefers the larger tolerances, the ones to the order of ± 0.004 in. or 0.005 in. per in. He tries to simplify all contours so as to avoid tricky production methods.

He sets up well integrated materials handling systems, salvages wax and investment materials, makes use of waste heat, installs automatic or semi-automatic machinery for every step he can, uses jigs and other tooling for clustering his dispensable patterns, and generally reduces every cost.

His setup is excellent for the largest production runs on parts of the widest tolerances and the simplest contours. But he is not limited to such parts. He can make whatever needs to be made, but he needs good sized production runs for economy.

The Metallurgist's Viewpoint

The metallurgist enters this field because it offers opportunities to apply his professional skill in the making of parts of strengths and qualities that have not been made before.

He agrees generally with the foundryman in keeping the tolerances up around the ± 0.004 in. per in. range, and in balancing production methods between casting and secondary operations. He is good on these secondary operations because he knows tool steels and what machine tools can be made to do. And he is expert on heat treatments as secondary strengthening means.

He can pick the exact alloy specification that will flow best and come to the most satisfactory accuracies in a given investment, and he can make sure that he gets that specification.

He may be less informed on the ceramics that go into investments, on the chemistry of waxes and other expendable pattern materials, and on the tool making that produces the molds. He surrounds himself with men who know these skills and he works willingly with them.

His shop is likely to be more flexible as to profitable sizes of orders and sizes of individual parts to be made. He can make profits on small runs as well as large ones. His shop is largely what the viewpoints of his associates make it. He likes jobs that depend largely upon the skillful handling of metals.

The largest and also some of the smallest castings seen during the gathering of data for this manual were made by shops headed by metallurgists and by foundries having excellent metallurgical staffs.

The Dentist-Jewelry Genesis Viewpoint

Historically, in the present continuous development which has brought the process to its present industrial stage, the dentists had precision investment casting first and the jewelers had it second.

Plants which have developed from that viewpoint like to do everything by casting methods and to avoid secondary operations. They work either to accuracies in the most common 0.003 in. per in. range and finer, or else they go to the extreme of 0.008 in. per in.

They are excellent at doing tricks with rubber parts and with inserts in the molds to produce unusually difficult interior and exterior contours. They are likely to be the first to make the process do new "impossibilities."

They are geared to take very large orders at satisfactory prices and to take medium sized ones. They also can take the smallest of orders at satisfactory prices. For example, a shop of this kind can produce all of the smaller parts for an experimental machine, and can keep on varying those parts as the trial runs of the machine indicate changes. They seldom like to make parts over 5 in. on any dimension or over 2 lb. in weight.

The Die Caster's Viewpoint

The die caster is likely to inject his patterns and pour his metals under high pressures and vacuums; pressures up to 500 lb. and vacuums up to 30 in. This leads to extreme soundness in the castings, excellent control of all processes, high finishes and high accuracies.

He prefers to do everything by casting and to avoid secondary operations. His tool costs for molds are high, he prefers the medium range of parts, sizes and contours; he can work to accuracies of ± 0.002 in. per in. or to anything that the vagaries of metals shrinkage will permit. His accuracies are likely to be high on all dimensions.

His tools and methods costs limit him to medium and larger production runs for profits. He can compete for most of the business, but when he finds a job that fully fits his shop he is unbeatable. Many of the advances in the art are originating from his methods.

The Toolmaker's Viewpoint

The toolmaker enters the field because he sees opportunities in the making of tools and dies for the dispensable patterns. He uses moving parts to cut threads on the patterns, to punch recesses and holes in them, to generate other contours. He makes quick opening molds and dies for speedy injecting and ejecting. He is excellent at temperature control of the molding.

He shares with the foundryman and the metallurgist the balancing of operations between casting and secondary processes but his is the viewpoint, not of deciding what can best be done by a process or a method, but of thinking of what can be done by tools with machines as mere means for driving them.

He works by preference to the highest accuracies that the casting process can produce, he likes ± 0.0005 in. But he does not know ceramics or metallurgy and therefore his shop is largely what his associates make it. Because of his tool costs he is best at medium and large sized runs. He does well on extremely small parts since he knows how to make multiple recess molds and dies and to mold large numbers of tiny patterns at a single injection.

He can handle any sizes and weights of parts that his metallurgist knows how to cast.

The Plastics Viewpoint

Plastics molders see in the molding of the dispensable patterns a chance to use some of their most highly developed injection molding techniques and materials. To a large extent they are content if they can get orders to produce these patterns and leave the investing and casting to casting shops.

When they get completely into the casting business they are likely to work to the wide tolerances of ± 0.004 in. and well within the average ranges of all other factors. To the extent that they use plastics as dispensable patterns they need fairly large production runs to justify the setting up of their injection machines.

The Equipment and Supplies Maker's Viewpoint

These companies are interested in the development of the process in order to sell more equipment and supplies to more casters who are getting more orders. In this interest, and also to make profits, they take on contract work. This is a common situation in industry. Makers of automatic screw machines make screw machine products on contract, makers of die casting machines are producers of die castings, and so on.

In the interest of development they will work to the finest tolerances, attack the most difficult metallurgical problems, make the largest and also the smallest castings.

Some of them will take contracts to develop a series of castings for a given customer, working out the most profitable tolerance range and the best balance between casting and secondary operations and the best alloys for the parts, paying for this development largely or wholly by their profits on the contract work, all for the purpose of working out a production line to be installed in the plant of the customer and selling him the necessary equipment and supplies. A large part of these development costs may be paid by subsequent royalties which will be charged the customer for operating under their patents.

Patterns and Molding

The original and most widely used dispensable pattern material is wax. Plastics of many varieties, especially the polystyrenes, are coming on rapidly and are used almost altogether by some casters. Many "waxes" are mixtures of waxes and plastics. Plastics which can be molded in the same molds and dies and at the same temperatures and pressures as waxes are newly developed; their exact place in the industrial picture is not yet established.

Waxes having melting points over 170 F are known as "high melting point." Molding pressures over the 30 psi. generally obtainable with centrifugal molding machines are known as high pressures, but since wax can be molded at pressures as high as 200,000 psi. this definition is weak.

There are two contests in the wax picture: the high melting point men *vs.* the low melting point men, and the high pressure men *vs.* the low pressure men. A high melting point man may be a low or a high pressure man, and so on.

High melting point waxes will stay hard at any temperature a room is likely to reach, therefore there is less distortion of patterns when employees are handling them on hot days. Low melting point waxes will sting but not seriously burn the skin if operators splash them, therefore they are less of an industrial hazard and operators are claimed to be able to handle them with impunity and therefore to work faster.

A wax always has a softening or mushy range which precedes its melting point. For molding at any pressure up to 200 psi. this should be narrow and the melting point sharp; a softening range that extends over 8 F (example, softens at 205 to 212 F, melts at 213 F ± 3 F) and a melting point that is sharp within 2 or 3 deg. is excellent. Narrow softening and sharp melting mean sharp molding and quick setting up or hardening of the pattern so it can be handled without distorting.

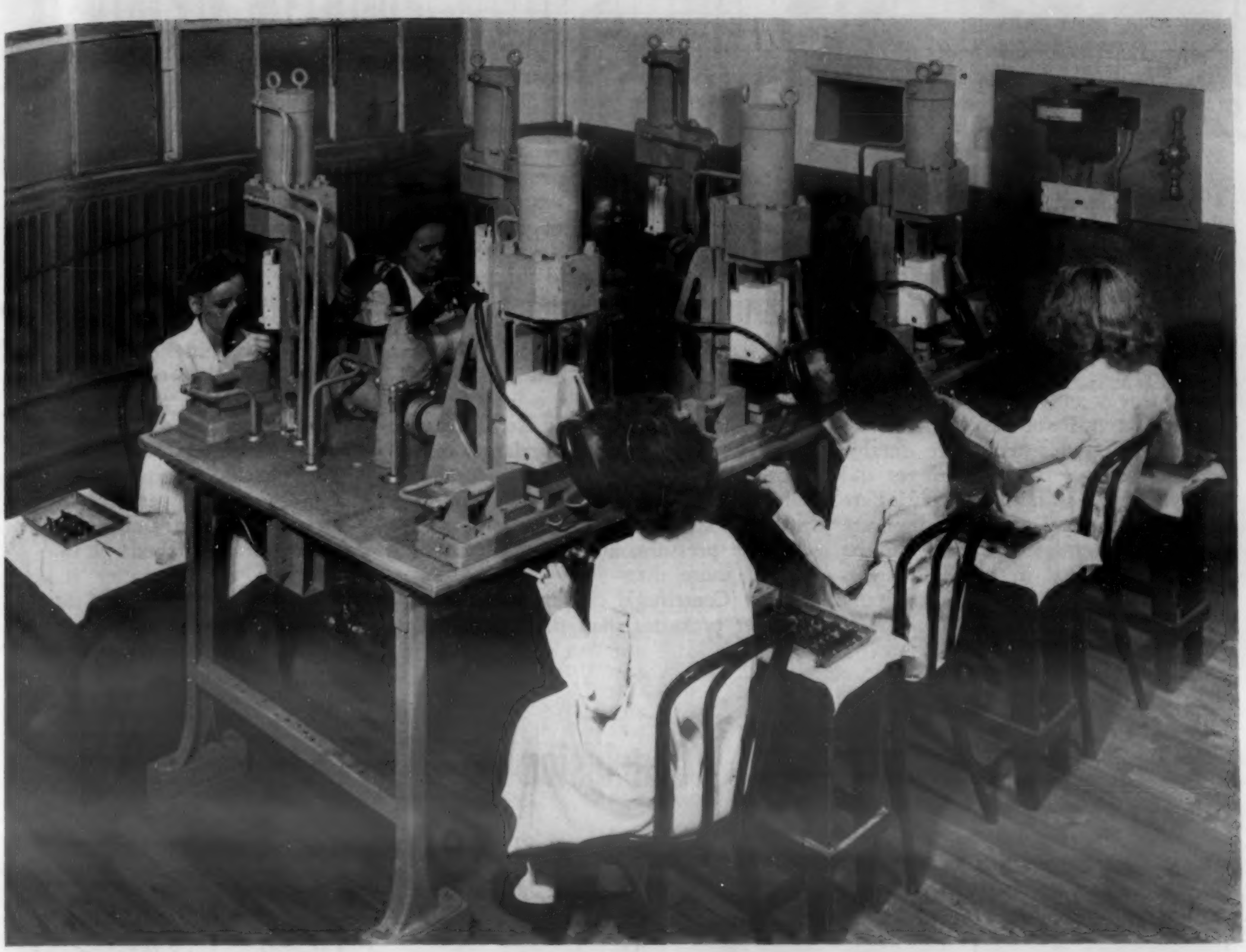
For molding pressures above 1000 psi. a much wider softening range can be desirable. The object of high pressure molding is to mold at lower temperatures thus reducing the temperature range through which the pattern must cool and lessening its shrinkage. The high pressure wax is softened but not melted at its injection temperature. The wider the softening range the more the combinations of pressure and temperature that can be used to obtain specific effects in the pattern.

Costs of wax run all the way from \$0.20 to \$1.50 a pound, with the usual range from \$0.60 to \$0.80. Waxes vary widely in specific gravities, but a useable average figure is that a cubic foot of wax weighs 20 lb. Since the volume of wax used will be roughly approximate to that of castings and sprues produced the cost of wax for a given lot of castings can be estimated from volume and weight. A rule of thumb figure is that the weight of wax used is one-eighth of that of the finished castings.

The price paid for wax has a general relationship to the thickness of sections and the fineness of details of the castings. When all sections are thick and there are no fine details or close accuracies the lowest cost wax can be used. Under opposite conditions, however, especially when molding is low temperature and low pressure, the costliest waxes may be needed.

Waxes can be reclaimed by melting them out before they burn out. This reclaiming is of two kinds: Salvaged waxes that are good only for sprues and gates, and, fully reclaimed waxes that can be mixed with new wax and used for all purposes.

Full reclaiming needs filtering of the waxes at a cost of about \$0.12 a pound, followed by laboratory testing to find out how to select the fresh ingredients to arrive at a satisfactory final mixture. The economic value of it depends largely upon the ratio in pounds of finished castings to sprues and gates. One caster uses comparatively small invested flasks, gets more than 5 lb. of castings for every pound of sprues and gates, would have to junk nearly all of his salvaged wax if he could not fully reclaim it, and in his shop 75% of every mixture of wax



In this precision investment casting plant the operators are injecting wax into the molds to form the wax patterns. (Courtesy: Kerr Dental Mfg. Co.)

for molding is reclaimed wax. Another caster uses very large flasks, gets only 4 lb. of castings for every 6 lb. of sprues and gates, and can use all of his salvaged wax for sprues and gates without going to the costs and troubles of fully reclaiming it.

Plastics have the advantage that if a caster has insufficient molding capacity he can have his patterns produced by the nearest injection molding contractor. They can be handled more roughly and carelessly than waxes, but their superiorities over many of the waxes in that respect have been grossly exaggerated in some published material, to the bedevilment of casters whose customers have then demanded that impossibilities be done with the plastics patterns. They are not inherently more accurate than the waxes, they are not immune to warpage or run out or size changes caused by internal stresses set up in their molding, their users do not automatically work to closer tolerances than the users of waxes.

The comparison of plastics to waxes or of one good wax to another can be summed up in a statement that when a caster learns how to use any one of them well, then he can get good results with it. The same statement applies to tool steels, machine tools and golf clubs.

Mold and Die Materials

Molds can be made of rubber, plastics, hydrolized wood, low shrinkage "soft metal" bismuth-tin alloys, aluminum, steel and other materials. Soft metal, steel and rubber seem to be the most frequently used, and in that order, with aluminum coming along rapidly.

Rubber molds have been sold far too short by most casters. For wide ranges of work they are the quickest and easiest to make and by far the least costly. They will pick up the finest details, and in the hands of men who know how to use them and perhaps to reinforce them with metal parts they can produce to better than average accuracy. For experimental work a rubber mold often can be made in 20 min. as compared to 20 hr. for any other; they could cut thousands of dollars a year from the pilot operations costs of many a plant. A wide variety of tricks can be worked out for the use of soft rubber cores and

inserts for the producing of difficult contours in molds made of any materials.

Soft metal molds can be cast, hobbed or machined to shape. If reinforced by being mounted in steel shells they can be used for injection pressures of several hundred pounds. Wear on them can be prevented by so using the steel shells that the mold sections meet steel to steel instead of soft metal to soft metal. They often can be repaired by soldering and building up when worn. They can be sections or liners of dies having mechanical motions made of steel parts, the soft metal being least costly for the contour molding parts and the steel more durable for the movable pins, the hinges and like parts. When multiple cavities are wanted, or several molds of duplicate or like sizes, master patterns can be made up, molded in rubber, dispensable patterns of the sizes and contours of the soft metal molds thus made, and the molds be produced by the precision investment casting process.

Steel molds are the most durable on long production runs. They usually are the most costly, but this statement can be deceptive. When the part is of such shape that the steel mold or die can be made by simple drilling, reaming and milling operations, the steel mold can be less costly to make than even a rubber mold for the same part.

Casting Methods

Casting almost always is under pressure, although gravity or "static" casting is coming into use for larger castings. Pressures range from 3- to 500-lb. Up to about 30 lb. they can be applied either by centrifugal force or by air pressure, and this range will cover more than 90% of all operations. Centrifugal casting can achieve higher pressures than that, of course, but in this field it rarely is called upon to do so.

Increasing amounts of casting are done under vacuums as high as 30-in. Controlled atmospheres at the casting machines are coming into considerable use.

One furnace melts the metal under 30-in. vacuum, applies inert gases if desired, then pours under vacuum followed by 500-lb. pneumatic pressure. This method produces sound castings unusually free from internal porosities.

Casting machines capable of pouring no more than one invested flask every 5 min. are proving profitable. Automatic set ups that will pour one invested flask every second are in use.

The melting equipment is highly varied. It employs gas fired, oil fired, electrical resistance and electrical induction heating methods. A high percentage of casters prefer induction heating for its speed and its close controllability.

Conclusion

Precision investment casting is a comparatively undeveloped industrial art, but it has reached the stage where it is reducing costs and improving qualities on tens of thousands of products. It is capable of accuracies roughly approximate to those of grinding. It can handle practically any metal that can be cast at all. The process makes its most valuable contributions by producing intricacies in parts and by handling with ease metals that are difficult or even impossible to fabricate economically by other methods.

It is not a process that "anyone can operate in a garage or cellar." Anyone entering it without previous experience or without high grade technical advice is likely to spend at least a year of time and large sums of money before he operates successfully.

It has well established contractors who will produce parts at low costs, and these contractors have developed enough differing techniques so they are well on their way toward dividing its field among them.

It is leaving the manual craftsmanship industrial category and is rapidly being mechanized. The successful shop of the future undoubtedly will have an invested capital of at least $5,000 per production line employee, and in addition, it will also have a highly paid and broadly trained technical staff.

Acknowledgment

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Producers of Precision Castings

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A. R. D. Corp., New York
Arocast Corp., Summit, N. J.
Austenal Laboratories, Inc., New York
Baker Casting & Jewelry Corp., New York
Bergen Precision Castings, Inc., Pleasantville, N. Y.
Crucible Steel Co., Harrison, N. J.
Cuker Process Co., New York
Delloy Metal Corp., Philadelphia
Ford Motor Co., Detroit
General Electric Co., Schenectady, N. Y.
Haynes Stellite Co., Kokomo, Ind.
Illinois Precise Casting Co., Chicago
International Nickel Co., Inc., New York
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Glyco Products Co., Brooklyn
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Joseph Robinson, precision castings consultant, New York also provided some information used in this Manual.

MATERIALS & METHODS Engineering File Facts

NUMBER 109
March, 1946

Standard Alloy Designations for Heat and Corrosion Resistant Castings

Designation	% Nickel	% Chromium	% Carbon	% Other Elements
CA-14	1 max.	11 to 14	0.14 max.	—
CA-40	1 max.	11 to 14	0.20 to 0.40	—
CB-30	2 max.	18 to 22	0.30 max.	—
CC-35	3 max.	27 to 30	0.35 max.	—
CD-10 M	3 to 6	27 to 30	0.10 max.	Molybdenum 2.00 max.
CE-30	8 to 11	27 to 30	0.30 max.	—
CF-7	8 to 10	18 to 20	0.07 max.	—
CF-10	8 to 10	18 to 20	0.10 max.	—
CF-16	8 to 10	18 to 20	0.16 max.	—
CF-20	8 to 10	18 to 20	0.20 max.	—
CF-7 Se	8 to 10	18 to 20	0.07 max.	Selenium 0.20 to 0.35
CF-7 C	8 to 10	18 to 20	0.07 max.	Columbium 10×Carbon
CF-7 M	8 to 10	18 to 20	0.07 max.	Molybdenum 2.5 to 3.5
CF-10 M	8 to 10	18 to 20	0.10 max.	Molybdenum 2.5 to 3.5
CF-16 M	8 to 10	18 to 20	0.16 max.	Molybdenum 2.5 to 3.5
CF-7 MC	8 to 10	18 to 20	0.07 max.	Molybdenum 2.5 to 3.5, Columbium 10×Carbon
CG-7	10 to 12	20 to 22	0.07 max.	—
CG-10	10 to 12	20 to 22	0.10 max.	—
CG-16	10 to 12	20 to 22	0.16 max.	—
CG-16 Se	10 to 12	20 to 22	0.16 max.	Selenium 0.20 to 0.35
CG-7 C	10 to 12	20 to 22	0.07 max.	Columbium 10×Carbon
CG-7 M	10 to 12	20 to 22	0.07 max.	Molybdenum 2.5 to 3.5
CG-10 M	10 to 12	20 to 22	0.10 max.	Molybdenum 2.5 to 3.5
CG-16 M	10 to 12	20 to 22	0.16 max.	Molybdenum 2.5 to 3.5
CG-7 MC	10 to 12	20 to 22	0.07 max.	Molybdenum 2.5 to 3.5, Columbium 10×Carbon
CH-10	10 to 12	23 to 26	0.10 max.	—
CH-20	10 to 12	23 to 26	0.20 max.	—
CH-10 C	10 to 12	23 to 26	0.10 max.	Columbium 10×Carbon
CH-10 M	10 to 12	23 to 26	0.10 max.	Molybdenum 2.5 to 3.5
CH-20 M	10 to 12	23 to 26	0.20 max.	Molybdenum 2.5 to 3.5
CH-10 MC	10 to 12	23 to 26	0.10 max.	Molybdenum 2.5 to 3.5, Columbium 10×Carbon
CK-25	19 to 21	23 to 26	0.25 max.	—
CM-25	19 to 22	8 to 11	0.25 max.	—
CN-25	23 to 26	18 to 22	0.25 max.	—
CS-25	29 to 32	8 to 12	0.25 max.	—
CT-25	34 to 37	13 to 17	0.25 max.	—
HB	2 max.	18 to 22	—	—
HC	3 max.	27 to 30	—	—
HD	3 to 6	27 to 30	—	—
HE	8 to 11	27 to 30	—	—
HF	8 to 11	18 to 23	—	—
HH	10 to 13	23 to 27	—	—
HI	13 to 16	26 to 30	—	—
HK	19 to 21	23 to 26	—	—
HL	19 to 21	28 to 32	—	—
HN	23 to 26	18 to 22	—	—
HP	29 to 31	28 to 32	—	—
HS	29 to 32	8 to 12	—	—
HT	34 to 37	13 to 17	—	—
HU	37 to 40	17 to 21	—	—
HW	59 to 62	10 to 14	—	—
HX	65 to 68	15 to 19	—	—

Designations with the initial letter "C" indicate alloys generally used to resist corrosive attack at temperatures less than 1200 F. Designations with the initial letter "H" indicate alloys generally used under conditions where the metal temperature is in excess of 1200 F.

All of the above designations apply to type compositions and no attempt is made to cover elements such as manganese, silicon and, in the case of heat resistant alloys, carbon.

Compiled by the Alloy Casting Institute

NUMBER 110
March, 1946

Common Specifications for Silver Brazing Alloys[2]

The family of silver brazing alloys (sometimes called "hard solders" or "silver solders"—although the term "silver solders" should only be applied to the lower melting point, about 500 to 700 F, alloys containing 1 to 5% silver) includes a range of materials containing 10 to 80% silver. The working temperatures of this class of silver alloys varies from 1100 to 1600 F, depending upon their composition.

These silver alloys possess several favorable characteristics (exclusive of their low melting point, conductivity, resistance to corrosion, ductility and malleability) that make them important metal-joining materials: the molten brazing alloys have excellent penetration properties, thus making fillets and large clearances unnecessary for good joints; a silver brazed joint may have a tensile strength as high as 120,000 psi. (the joint, if properly designed and fabricated, is often stronger than the metals being joined).

Specification		Composition, Per Cent					Working Temperature (Liquidus)	Color
Designation	Grade	Ag	Cu	Zn	Cd	Others		
ASTM B73-29	1	10	52	38	0.50 max.	0.15[1]	1600	Yellow
USN 47S13c USA Chem. Warfare Serv. 196-131-80[3] USAAF 11342 FED. QQ-S-561b	III 3 A 3	15	80	—	—	P 5	1300	Gray-white
ASTM B73-29 USN 47S13c USA Chem. Warfare Serv. 196-131-80[3] FED. QQ-S-561b	2 0 0 0	20	45	35	0.50 max.	0.15[1]	1500	Yellow
ASTM B73-29	3	20	45	30	5	0.15[1]	1500	Yellow
ASTM B73-29 USN 47S13c USA Chem. Warfare Serv. 196-131-80[3] FED. QQ-S-561b	4 I 1 1	45	30	25	nil	0.15[1]	1370	Nearly white
ASTM B73-29	5	50	34	16	nil	0.15[1]	1425	Nearly white
USN 47S13c USA Chem. Warfare Serv. 196-131-80[3] USA Ord. Dept. (Tent.) AXS-741 USAAF 11342 FED. QQ-S-561b AMS 4770	IV 4 4 B 4 —	50	15.5	16.5	18	0.15[1]	1175	Yellow-white
USA Chem. Warfare Serv. 196-131-80[3]	5	50	15	15.5	15.5	Ni. 3.0 0.15[1]	1270	Yellow-white
ASTM B73-29 USN 47S13c USA Chem. Warfare Serv. 196-131-80[3] FED. QQ-S-561b	6 II 2 2	65	20	15	nil	0.15[1]	1325	White
ASTM B73-29	7	70	20	10	nil	0.15[1]	1390	White
ASTM B73-29	8	80	16	4	nil	0.15[1]	1460	White

[1] *Impurities, maximum.*
[2] *Data from ASTM Standard Specifications for Silver Solders, B73-29; from Table 62, p. 433 of Circular C447, National Bureau of Standards, and from information furnished by Handy and Harman Co.*
[3] *Recently this CWS specification has been superseded by Federal Specification QQ-S-561b.*

Compiled by Robert S. Burpo, Jr., Associate Editor

THE MOMENT

WEAR IN

STOPS...

WEAR OUT

STARTS

With stainless steel too...

A certain amount of "wear in" or "running in" is essential to lap parts to the point of peak efficiency. After that "wear out" begins. The engineer's constant struggle is to increase the life of parts subject to wear.

Even when you use stainless steel, "wear out" is a factor. That's why so many manufacturers or users of stainless steel parts have turned successfully to the Stainless Surface Hardening Company's process (Malcomizing) for developing a hard nitrided case to resist "wear out."

In this new process lies the answer to the problem of how to get increased abrasion resistance to add to the well-known corrosion resistance of the stainless steels. Write today sending us your parts or blueprints for an analysis of the applicability to your product of the Stainless Surface Hardening Company's process.

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MATERIALS & METHODS Engineering File Facts

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March, 1946

MATERIALS: Steels for High Temperature Uses

Properties of Steels for High Temperature Service[1]

Table 1. Composition and room temperature physical properties of steels used in high temperature service
(For a summary of the properties of these same steels at elevated temperatures, see Table 2, p. 771)

Steel		Composition, Per Cent							Heat[4] Treatment	Physical Properties					
No.	Type[3]	C	Mn	Si	Ni	Cr	Mo	Others		Tensile Strength[2]	Yield Point[2]	Elong. %	Red. of Area %	BHN	Charpy Impact, Ft-Lb.
1	SAE 1030	0.28	0.64	0.25	—	—	—	—	as rolled	71.4	46.4	27.8	58.4	153	43.0
2	SAE 1035	0.36	0.53	0.19	—	—	—	—	as rolled	77.5	46.5	24.8	52.4	156	32.4
3	Cr-Si	0.36	—	1.2	—	1.3	—	—	OQ 1615 OT 1020	133.0	117.8	12.7	57.6	240	39.4
4	Cr-Si-Mn	0.32	1.08	1.04	0.21	0.93	—	—	OQ 1615 AT 1110	121.5	102.1	14.8	65.9	231	47.5
5a	Mn-Si-Mo	0.37	1.93	1.47	—	—	0.35	—	OT 1270	113.5	97.3	16.1	60.8	220	41.5
5b	Mn-Si-Mo	0.37	1.93	1.47	—	—	0.35	—	OQ 1580 T 1020	155.6	140.2	9.8	48.6	300	25.4
5c	Mn-Si-Mo	0.37	1.93	1.47	—	—	0.35	—	OQ 1580 T 570	223.9	192.0	5.8	48.1	380	9.9
6a	SAE X4130	0.23	—	—	—	0.93	0.26	—	OQ 1615 OT 1110	119.5	105.3	11.5	65.0	220	77.5
6b	Cr-Mo	0.33	0.42	0.3	0.35	1.62	0.58	Al 1.21	AQ 1740 FT 1200	113.1	89.9	15.0	64.2	230	86.2
7	SAE 3340	0.44	—	—	3.31	1.38	—	—	OQ 1740 AT 1065	149.4	140.1	9.9	52.7	320	32.4
8	Cr-V	0.44	0.59	0.36	0.34	0.88	—	V 0.2	OQ 1615 AT 1110	95.6	51.2	21.4	54.0	180	19.3
9	Cr-Mo-V	0.24	0.50	0.31	0.15	1.70	0.25	V 0.30	OQ 1615 OT 1200	166.0	151.6	7.5	54.7	335	79.6
10	Cr-Mo-V	0.44	0.40	0.27	—	1.40	0.46	V 0.26	OQ 1615 OT 1200	126.2	113.8	10.5	62.7	330	61.4
11	Cr-Ni-W	0.21	—	—	3.61	1.28	—	W 1.08	OQ 1560 OT 1065	129.6	110.7	18.6	68.0	290	74.0
12	Cr-Ni-V	0.21	0.35	0.25	3.96	1.06	—	V 0.29	OQ 1560 OT 1075	127.3	105.2	14.7	63.6	246	26.8
13	Cr-Ni-W	0.22	0.34	0.37	4.27	1.51	0.34	—	OQ 1560 FT 1200	150.8	135.6	10.2	63.3	280	72.0
14	Cr-Ni-W	0.38	0.45	0.25	1.43	0.72	0.22	—	OQ 1560 AT 1075	101.1	53.1	17.0	39.1	194	22.8
15	Cr-Ni-W	0.65	—	—	1.59	0.71	0.25	—	OQ 1510 OT 1110	153.9	148.4	9.5	52.2	230	68.8
16	Cr-Ni-W	0.42	0.37	0.30	4.33	0.70	1.04	—	OQ 1830 FT 374 OT 1155	158.6	85.3	9.2	33.2	—	31.4

[1] *Data taken from Stahl und Eisen, No. 3-4, 1943, pp. 42-47.*
[2] *In thousands of lb. per sq. in.*
[3] *Where SAE types are given, it indicates that the original material conforms, in general, to the appropriate American standard steel specification.*
[4] *OQ=Oil quench; AQ=Air quench; OT=Temper and cool in oil; AT=Temper and cool in air; T=Temper; FT=Temper and cool in furnace.*

(Continued on page 771)

War-born  Ideas

for Peacetime  Products:

LIGHTWEIGHT PARTS with HEAVYWEIGHT RUGGEDNESS from B&W TUBES . . .

FOR every *one* pound saved in track weight, Army Ordnance Engineers found, an extra *five* to *seven* pounds could be added to the main body of a tank above the springs . . . in heavier armor, greater ammunition storage. Track weight of the famous M-4 tank, for example, was cut by *780 pounds*...by making the track "pins" from light, yet rugged mechanical *tubes* developed and manufactured for the job by B&W!

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And B&W Tubes bring production economy, too. Better parts can be produced in less time than with solid stock, and with fewer operations, greater uniformity and less scrap loss. B&W Tubes for mechanical uses can be furnished in a wide range of analyses from low carbon to high alloy steels. Hot-finished and cold-drawn tubing can be upset, swaged, expanded, bent, spun, and otherwise formed to users specifications, and with special surface finishes.

Babcock & Wilcox will gladly share with designers its rich fund of cost-cutting ideas for making better parts from seamless or welded tubing. Get in touch with B&W today.

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TA-1354

Table 2. Variation in Physical Properties with Temperature (For Steels Listed in Table 1.)

2a. Variation in Charpy Impact Value with Temperature

Steel No.[1]	Temperature, Degrees F									
	−76	−40	−4	32	212	392	572	752	932	1112
2	—	—	23.8	30.4	36.4	41.5	37.0	35.4	30.4	38.0
3	27.9	32.0	31.4	38.0	49.1	49.6	44.1	40.5	35.4	45.1
7	26.3	32.9	32.9	30.9	44.1	43.0	41.5	39.5	33.9	43.0
9	72.4	72.9	67.8	76.0	76.5	81.0	70.9	69.9	54.2	64.8
11	49.1	50.6	111.4	70.9	74.9	80.5	74.9	63.3	54.7	—
12	—	—	26.3[2]	27.9[3]	31.4	49.1	50.1	46.6	41.5	52.7
15	54.7	55.2	47.1[4]	63.3	70.0	63.8	55.7	55.7	37.5	—
16	—	—	—	20.3[3]	35.4	50.1	45.6	49.6	39.5	—

2b. Variation in Yield Strength[6] with Temperature

Steel No.	68	212	392	572	752	932	1112
2	46.9	44.1	38.4	28.5	25.6	22.8	11.4
3	118.1	102.4	98.1	93.9	68.3	39.8	—
6a	106.7	93.9	99.6	101.0	89.6	83.9	25.6
7	139.4	128.0	120.9	116.6	96.7	44.1	19.9
8	49.8	45.5	39.8	38.4	37.0	28.4	19.9
9	150.8	133.7	139.4	136.6	128.0	103.8	55.5
10	145.1	128.0	119.5	112.4	110.9	79.7	32.7
11	109.5	102.4	99.6	95.3	86.8	65.4	54.1
12	105.3	99.6	96.7	95.3	85.3	62.6	28.5
15	128.0	130.9	125.2	112.4	92.5	54.1	15.7
16	135.1	122.3	118.1	110.9	109.5	68.3	28.5

2c. Variation in Tensile Strength[6] with Temperature

Steel No.	68	212	392	572	752	932	1112
2	78.2	71.1	82.5	82.5	71.1	49.8	27.0
3	130.9	122.3	122.3	125.2	98.1	70.0	31.3
6a	118.1	113.8	142.2	120.9	108.1	95.3	68.3
7	150.8	140.8	140.8	139.4	109.5	78.2	31.3
8	93.9	85.3	82.5	92.5	78.2	52.6	31.3
9	167.8	153.6	156.5	156.5	147.9	126.6	86.8
10	120.9	146.5	130.9	123.7	122.3	98.1	62.6
11	128.0	120.9	118.1	116.6	106.7	85.3	46.9
12	128.0	116.6	116.6	115.2	98.1	82.5	17.1
15	155.0	145.1	132.3	125.2	123.7	85.3	46.9
16	157.9	135.1	135.1	132.3	103.8	79.2	42.7

[1] *For compositions of these steels, see Table 1, p. 769.*
[2] *At 68 F.*
[3] *At 122 F.*
[4] *At 14 F.*
[5] *In ft-lb.*
[6] *In thousands of lb. per sq. in.*

Compiled by Robert S. Burpo, Jr., Associate Editor

engineering SHOP NOTES

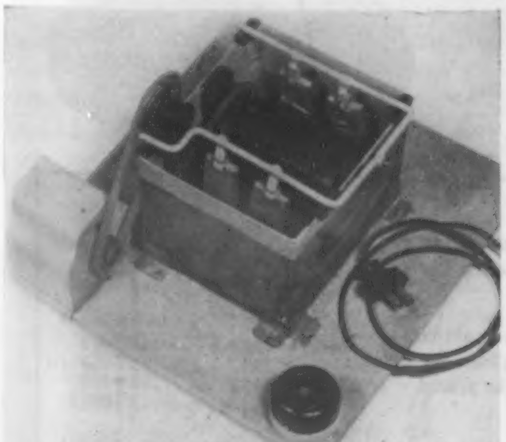
Micro Barrel-Plater

by H. S. Morgan,
Hamilton Watch Co.

Experience of the Hamilton Watch Co. is that it is impossible to obtain a manufactured barrel plater for small parts which will require only a small quantity of plating solution. Many such solutions are expensive.

Accordingly, engineers of the company constructed the extremely useful and practical small barrel-plater shown in the photograph.

Quantities of small parts can be satisfactorily plated without large or cumbersome equipment and volumes of solution. New and experimental plating solutions can be tried under simulated production conditions without requiring more than 1500 ml. of solution.



The entire assembly is mounted on a noncorrosive base, 1 ft. sq. A removable tank of stainless steel, coated on the inside with an acid-alkali resistant, insulating material prevents current loss and possible attack on the metal by corrosive solutions.

Two battery connectors, on each side of the barrel, provide for making contact and holding the anodes in position. These clamps also make possible a quick change of metal and anode-cathode area ratio.

The barrel is of hard rubber, perforated to allow the free flow of solution in and out of the barrel. Round metal tumblers are fastened to the inside of the barrel to provide cathode contact and to tumble the metal parts for uniform plating. In cases where immediate contact and circulation is advisable, the electric motor and current for plating can be turned on and the barrel containing the parts can be placed in the slots and dropped into place.

Simultaneously, the gears are meshed and the cathode contact is made so that plating will begin immediately. Power to rotate the barrel is furnished by a small electric motor and carried to the bottom of the tank through a train of hard rubber gears. Space is provided for a specially-designed immersion heater and thermocouple for automatic control of warm or hot solutions.

In the production plating of small parts an extra barrel can be made for these platers so that one lot of parts can be prepared and placed in the barrel while another lot is being plated. With proper adjustments good results have been obtained in plating cadmium, nickel, gold, silver, indium, cobalt-nickel, and copper from conventional solutions. Some other metals can, no doubt, be plated with equally satisfactory results.

These platers are unusually suited to experimental trials and investigations of new plating solutions. This is of particular value to the laboratory where many of the ideas on plating and metal finishes originate.

Removing Soldering Flux from Stainless Steel

By Arthur P. Schulze

Among the unusual production kinks encountered from time to time by various plants in fabricating stainless steel is the removal of acid flux from pickled finished sheets after soldering to prevent attack or staining of metal. The following is one means of handling the problem.

Usually, the entire part is thoroughly cleaned immediately after soldering while the flux is still liquid before it dries and hardens. One immerses the soldered work in a solution of Oakite No. 29 (or No. 30 or 37) detergent at room temperature. After "soaking" for a short period the work is brushed or rinsed.

Neutralizing the entire part, rather than the solder joint only, is advised because splattering and fumes from the flux may coat the metal with acid at points away from the joint itself, and will, if not removed, cause pitting and corrosion of surfaces. If flux has become oxidized and hardened, work is then treated with a certain acidic solution, such as Oakite, either No. 32 or No. 84.

Lead Welding With a Carbon Arc

by S. Craig Cairns,
Hobart Brothers Co.

Lead welding, sometimes inaccurately called "lead burning," heretofore has been done with the oxy-gas welding torch and welding rod, but here is the first time we can recall that lead has been successfully arc welded.

In preparing a room at Hobart Trade

School for installation of a 250,000 volt X-ray machine for testing of metals and welds, it was necessary that the floor and walls be lined with sheets of ⅛-in. lead to absorb the rays of the X-ray equipment and protect the area adjoining the testing room.

The walls were covered by lapping the lead sheets and nailing, but to lap the lead on the floor would result in bumps and eventual wearing and breaking of the lead. The floor is to be covered with asphalt tile blocks, and a smooth even job of laying the lead sheets was necessary.

The edges were butted and joined by arc welding, using a carbon arc torch and strips cut from the lead sheets for filler rod. Welding current of 15 amps, 15 volts was used from a Hobart 300-amp. arc welding machine, but fitted with a Hobart Thinweld attachment connected to the welding circuit to reduce the amperage to the 15 amp. required to weld the lead.

Joints were welded at the rate of 24 in. to 30 in. per min. by puddling the lead filler strips with a slight weaving motion. This work, of course, must be done in the down hand position and well backed up with steel or copper. In this case the lead sheets were being laid on a steel floor, which formed a perfect backing.

Cutting Tubing Rapidly

by H. G. Titus,
Youngstown Sheet & Tube Co.

Our shop received a rush order for 100,000 pieces of ½-in. diam. tubing in 41⅜-in. lengths, followed almost immediately by another for 250,000 pieces of 1-in. tubing in lengths of 22 11/16 in. Both were hurry-up orders for the seasonal trade.

The material could not be cut to size on our weld mill because tubing comes out too fast to be cut in such short lengths. The normal procedure for the 1-in. material would be to cut to near proper length with a cutoff saw, then ream to exact length. But this is a double process, slowing output and making considerable waste and allowing an output of 1,500 pieces in 8 hr., which was much too slow.

So we devised a rapid lathe cutoff. We took a scrap lathe, equipped it with a Zagar speed chuck, used spare bearings for the spindle and built a cross carriage to support the tool. We made a long wooden trough to support the material as it was being fed into the lathe.

The 1-in. material was cut into lengths of 19 ft. 6 in. on the welding mill; the ½ in. into 21 ft. lengths. From there they were taken to our improvised lathe cutoff. The material is fed into the lathe from the left. It comes to an adjustable stop, which gives the exact length, is clamped and cut off in seconds. Waste is almost eliminated.

With ½-in. tubing the output is 3,600 pieces in 8 hr.; with the 1-in. material, 3,500 pieces. The device has cut required time by 75%, and, of course, reduces scrap. It is adjustable so one can cut pieces from 1 in. to 6 ft. long.

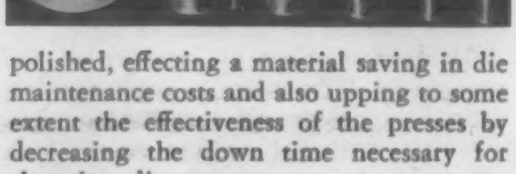
Cemented Carbides for Forming Stainless

By R. D. Mack,
Carboloy Co., Inc.

Gains in die life ranging from 10 to 1 to as high as 20 to 1 by the use of cemented carbides for three out of the four dies used on a certain forming operation on stainless steel is reported by Neu-Bart Stamping & Mfg. Co., Los Angeles. The concern was engaged in the manufacture of stainless steel sleeves for the exhaust system of B-24 planes.

The process is rather unusual since there is a small reduction in wall thickness of the stock through the operations. In producing the sleeves, a stainless steel blank of 0.063-in. thickness and 9 in. in diam. is first formed into a cup, 5½-in. in diam. The next three operations, performed with dies having Carboloy nibs, reduce the O.D. of the sleeve successively to 4 in., 3 in., and finally to 2⅜ in., as shown in the accompanying illustration.

Production figures show that the various types of high production steel dies previously used produced between 500 and 1,000 pieces, on an average, before regrinding. The Carboloy dies regularly turned out between 5,000 and 10,000 sleeves to required finish and dimensional tolerances before the dies had to be re-



polished, effecting a material saving in die maintenance costs and also upping to some extent the effectiveness of the presses by decreasing the down time necessary for changing dies.

Automatic Wire Chipper

D. Rozental & R. David Thomas, Jr.,
Arcos Corp.

For several years our laboratory has been using a wire chipping machine to provide fine chips from wire samples of various diameters for chemical analysis. The machine consists of a Boston Gear Works Ratiomotor (catalog number MD2848T, mounting A, ratio 48-1, low

speed 26 rpm, torque value 230) fitted with about a dozen high-speed Brown and Sharpe screw slotting cutters (catalog number H25, gage 20, hole 1 in.)

The wire to be chipped is held in a simple fixture supplied with an adjustable weight which is used to vary the force of the wire against the cutters. The force to be used depends on the diameter of the wire; the larger the diameter, the greater the force necessary. Once the wire is fixed in the machine, the chipping is completely automatic and no supervision is needed.

The advantages of this machine over other methods of obtaining samples are: (1) Fine chips obtained that are readily dissolved; (2) little time required to operate; (3) compact equipment easily located in a chemical analysis laboratory and always available for obtaining additional chips of a sample; and (4) easily operated by a laboratory technician rather than by a highly paid machinist.

A firm had the problem of silver brazing 1400 joints on certain fittings. The male parts were 1-in. copper pipe and the female parts were of a stainless steel that would take silver solder if proper heat were used. At first the solder ran toward the hottest point and the operators could not make it flow in all directions. Finally, a multiflame ring head was used in connection with an Oxweld W-17 welding blowpipe and the job was completed without further trouble.

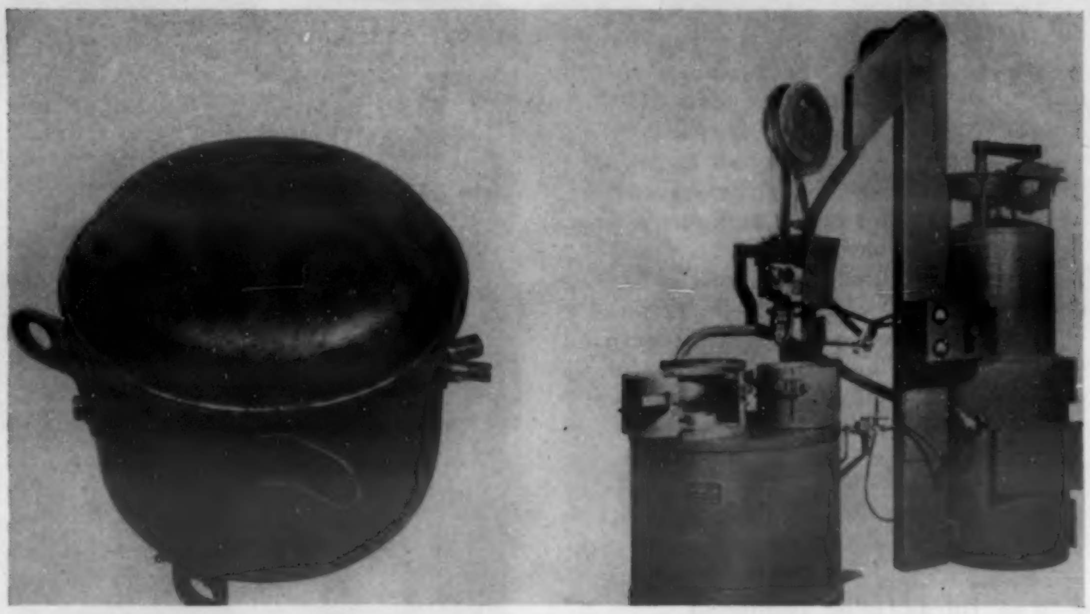
—"Oxy-Acetylene Tips,"
Linde Air Products Co.

Special Work-Handling Fixtures

By Cecil C. Peck,
Cleveland, Ohio

Often in welding jobs the unique shape of the parts to be welded do not lend themselves readily to handling and positioning by ordinary methods. Manufacture is slowed down and the usual advantages of mass production are not realized. However, there are designers and manufacturers whose specialty is to design and manufacture special fixtures for automatic welding of odd shapes and sizes.

An interesting case is the production of compressor units for refrigerators at the Richmond, Ind. plant of the Crosley Corp. These units measure 9½ in. in both diam. and height, and consist of two cup-shaped members fitted together and automatically welded around the circumferential seam to make it absolutely leak-proof. As a result of the use of a special fixture, the speed of welding and handling was increased to a production rate of one completely welded compressor unit per min.



The fixture has a specially designed flux recovery unit. All operations, except loading and unloading of the casing structures, are handled by electric power supplemented with a compressed air actuated lifting mechanism.

The formed steel body and end section of the casing are placed in one of three drums on the circular welding table. The drums are hinged to permit easy insertion and removal of the work. After inserting the parts, the drum is clamped shut and the entire table top is revolved by depressing a foot pedal. This releases the indexing mechanism and positions the work directly under the automatic welding head. The welding head, flux hopper and wire electrode reel are then lowered to the correct welding position by compressed air, and the drum and work revolves at a predetermined welding speed.

Flux is gravity fed through a tube ahead of the arc where it completely covers the arc and protects the hot weld deposit from the atmosphere while cooling. Excess flux is trapped in a circular dam arrangement located around the joint to be welded. During the 25 sec. for the automatic weld, another casing assembly is being clamped in the drum at one of the adjacent stations and a finished unit is being cleaned and removed from the drum at the third station.

When revolving the welding table from station to station, the entire welding head is raised up out of the way by a turn of the compressed air valve control lever located just above the foot pedal release for the indexing mechanism.

The granular flux used in the welding is recovered through a vacuum tube at the third station on the welding table. The flux is screened in the flux recovery unit and the reusable, salvaged flux is carried to the top of the vertical chute by a continuous small bucket-type belt conveyor. The flux is then dumped and returned to the flux hopper ready for re-use.

All structures comprising the special revolving welding fixture and flux recovery unit are of sturdy welded steel design.

At the left in the accompanying photograph is the compressor unit for the Crosley refrigerator after welding. At the right is the fixture itself, with the flux recovery unit at the right.

Replica Surface Analyzer

By Harry K. Herschman

A method for evaluating surface finish through the medium of a nearly transparent plastic replica of the surface was developed at the National Bureau of Standards.

Basically, its operation consists in passing a restricted beam of light through an oscillating test replica, thence through a restricting diaphragm onto a photoelectric cell. The light transmitted through the oscillating replica and reaching the cell is of variable intensity because of geometric characteristics of the replica from area to area scanned by the beam of light.

These fluctuations of intensity of the transmitted light cause a corresponding variation of electronic transmission, producing a pulsating voltage in the cell circuit which is recorded by an electronic voltmeter. This voltage increases with increased surface roughness.

Some of the salient features of this method of surface analysis are: (1) easy maintenance of a permanent record of a surface finish; (2) rapid average evaluation of a considerable length and width of surface at one setting; (3) simplicity of operation; (4) absence of the personal factor; (5) preservation of a surface, even for soft materials; and (6) availability of the method, since the replica may be prepared in one locality and transported to the location of the analyzer.

Results of recent experiments have indicated that this type of apparatus also may be applicable for evaluating the corrosion pitting of a metal.

Back-Stepping to Eliminate "Cupping"

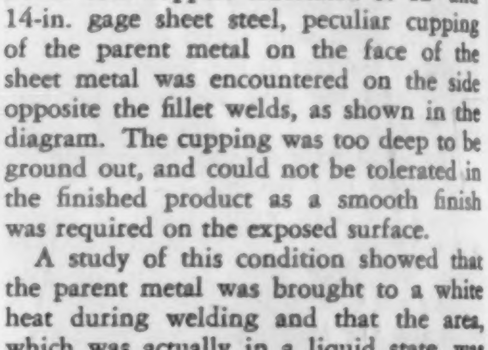
By John Plaskon,
Metal & Thermit Corp.

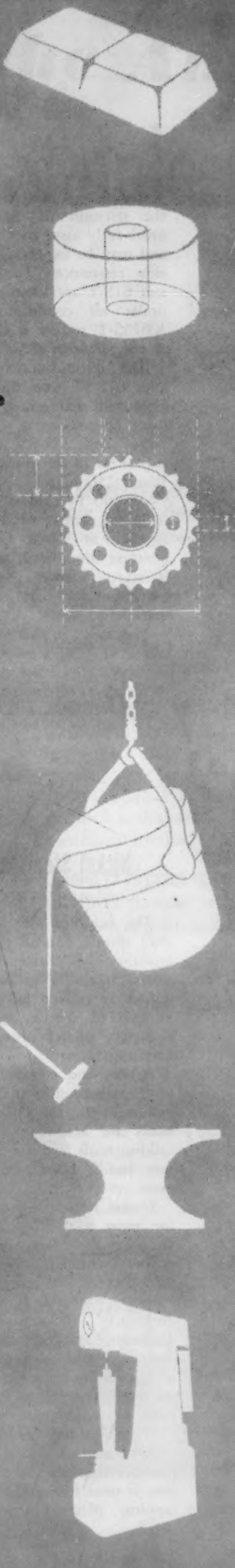
In the welding of automatic domestic stoker coal hoppers fabricated of 12- and 14-in. gage sheet steel, peculiar cupping of the parent metal on the face of the sheet metal was encountered on the side opposite the fillet welds, as shown in the diagram. The cupping was too deep to be ground out, and could not be tolerated in the finished product as a smooth finish was required on the exposed surface.

A study of this condition showed that the parent metal was brought to a white heat during welding and that the area, which was actually in a liquid state, was drawn in as a part of the weld metal mass as the weld deposit cooled. In an effort to correct the cupping condition, the amperage was reduced. This increased the time factor without lowering the heat input or causing any appreciable decrease in the cupping.

Genex, Alternex and Type U electrodes in the 1/8-in. size and both Genex and Alternex in the 3/32-in. size were tried without success when employing normal welding techniques. The problem was solved by using a "whip" technique by means of which the metal was deposited in short back-handed steps, as indicated in the chain sketch.

This method, properly used, prevented the parent metal from reaching a white heat and totally eliminated cupping, without loss in production speed. It was recommended that 1/8-in. Type U electrode be used since it is better adapted to the whip technique when using current.





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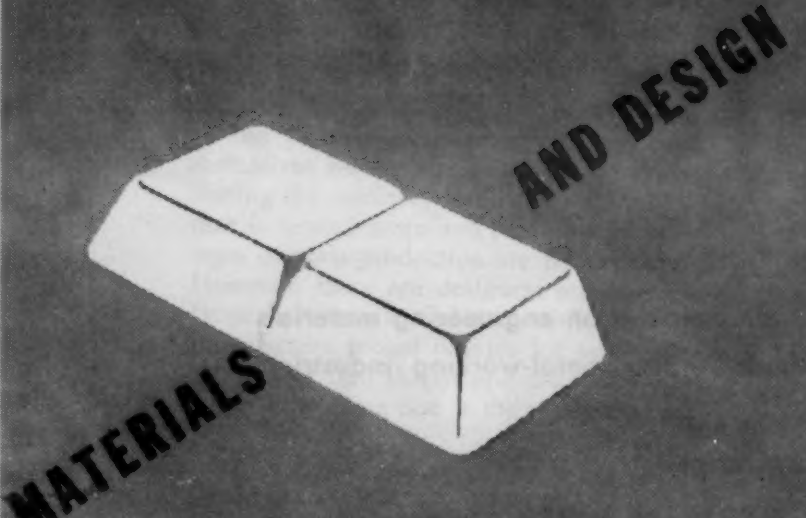


METALS and ALLOYS

Engineering properties and applications of carbon, alloy and stainless steels, irons and nonferrous metals and alloys. Selection and evaluation of metallic materials for engineering service. New alloys and modifications.

Aluminum for Elevated Temperatures

Condensed from "Metals Technology"

Aluminum sheet must sometimes be used where moderately elevated temperatures are encountered, and attention has been directed toward determining the influence of "artificial aging" on room-temperature properties. Two groups of materials were tested, Group A consisting of naturally aged alloys, 24S-T Alclad sheet, 24S-RT Alclad sheet, and 61S-W bare sheet; Group B consisted of 24S-T80 Alclad sheet, 24S-T81 Alclad sheet, 24S-T86 Alclad sheet, 61S-T bare sheet, and XB75S-T Alclad sheet.

Strains at elevated temperatures were measured by an extensometer, with times extending to 1000 hr. Temperatures of 75 F, 212 F, 250 F, 300 F and 375 F were used. As with other materials, creep may be a significant factor in elevated-temperature tests. Stress-rupture tests at 300 and 375 F indicate that eventual failure may occur under steady loading at stresses well below the value of the short-time tensile yield stress.

Associated with strength requirements is corrosion resistance. In 24S-T and 24S-RT a marked susceptibility is known to occur in the early stages of elevated-temperature aging. Corrosion resistance improves with continued aging, and approaches that of the original material. Corrosion problems may be expected to attend use of these alloys up to about 300 F. Use of 24S-T8 series may minimize these difficulties. XB75S-T and 61S-T may also be suitable for elevated-temperature service.

Members of the 24S-T8 series seem to offer the best possibilities for service at elevated temperatures. After sufficient exposure, 24S-T and 24S-RT may approach the strength of the 24S-T8 series, but until fully aged they are lower in strength and may be expected to be lower in corrosion resistance. The strengths of 61S-W and 61S-T are lower than those of 24S-T8 under all conditions tested, while the XB75S-T suffers a rapid loss of strength at temperatures above 250 F.

The effects noted in 24S-T, 24S-RT and 61S-W are those of marked precipitation hardening, followed in some cases by overaging. Tensile properties of 24S-T and 24S-RT are little affected by exposures of as much as 1000 hr. at 212 F and 250 F.

At 300 F there is a substantial increase in yield stress, while early overaging is apparent at 375 F. Even at the latter temperature the yield stress after 1000 hr. is scarcely lower than the 1/4-hr. value, but the ultimate stress has dropped markedly.

Materials in Group B show no decrease in yield strength in temperatures as high as 250 F, but at higher temperatures show effects of overaging.

—A. E. Flanigan, L. F. Tedsen & J. E. Dorn. *Metals Technology*, Vol. 12, Dec. 1945, Tech. Pub. No. 1929, 19 pp.

Nickel Steels and Cast Irons

Condensed from "Tool Engineer"

The selection of the proper low alloy steel should depend not only on its hardenability and fabricating properties but also upon its ability to meet the service conditions as proven by past performance. A number of specific applications are given with the nickel bearing steels that have been satisfactory.

Arbors and collets are sometimes made of direct hardening nickel-chromium-molybdenum steels. Direct hardening nickel alloy steels are also suitable for boring bars, calking tools, ring and thread gages, hammer heads, hobs, punches and hydraulic rams.

Nickel steels have given excellent service for most hand tool applications such as wrenches, hammers, screw drivers, pliers, nippers, chisels, punches and rivet sets. Nickel-chromium-molybdenum steel is almost the universal choice for drop hammer die blocks. Nickel steels are also used for die casting and for molding plastics. Nickel-chromium-molybdenum-tungsten steels have given good service in mandrels, dies and containers of presses for extruding aluminum, brass and high nickel alloys.

Nickel additions improve the machinability, structure, uniformity, density and pressure tightness of cast iron. Nickel cast iron is used for surface plates, angle plates, lapping plates, jigs, fixtures, bushings,

sleeves and bearings. It has also been used extensively for forming dies, as well as for lighter weight, thinner sectioned castings such as cylinder liners, small gears and lightweight machinery frames and housings. Nickel-chromium cast iron is used for beds, saddles, tables, spindles, small gears, and hydraulic valve parts. It is also suitable for wear resisting castings, such as pulleys, dies and cams.

Nickel-molybdenum cast iron is satisfactory for crankshafts, gears, tool shanks, and machine parts requiring high strength. The tensile strength of all these cast irons can be increased by about 15,000 to 25,000 p.s.i. by oil quenching and tempering.

Some applications have been made of the nickel bearing stainless steels and of Ni-Resist. There are a few specialized applications where nonferrous alloys such as K, S, M and Z Nickel have distinct advantages due to their corrosion resistance and nonsparking characteristics.

Alloys of the Invar type with about 36% nickel have low thermal expansion properties and are therefore useful for gages, and fixtures used in conjunction with parts that require dimensions finished to extremely close tolerances. Nickel containing permanent magnets of the Alnico type are used for "nonelectric" magnetic chucks.

—T. N. Armstrong & J. S. Vanick. *Tool Engineer*, Vol. 15, Nov. 1945, pp. 24-30.

German Stainless Steels

Condensed from "The Iron Age"

Data are presented, mostly in tabular and graphical form, showing the types of stainless steels and high-temperature alloys commercially produced in Germany during the critical period of the war.

Two high-temperature alloys, designated as Tinidur and CMV Special (Cromadur), were developed by the Krupp Co. specifically for use as blading material for the gas turbine of the Junkers 004 Jumo jet-plane.

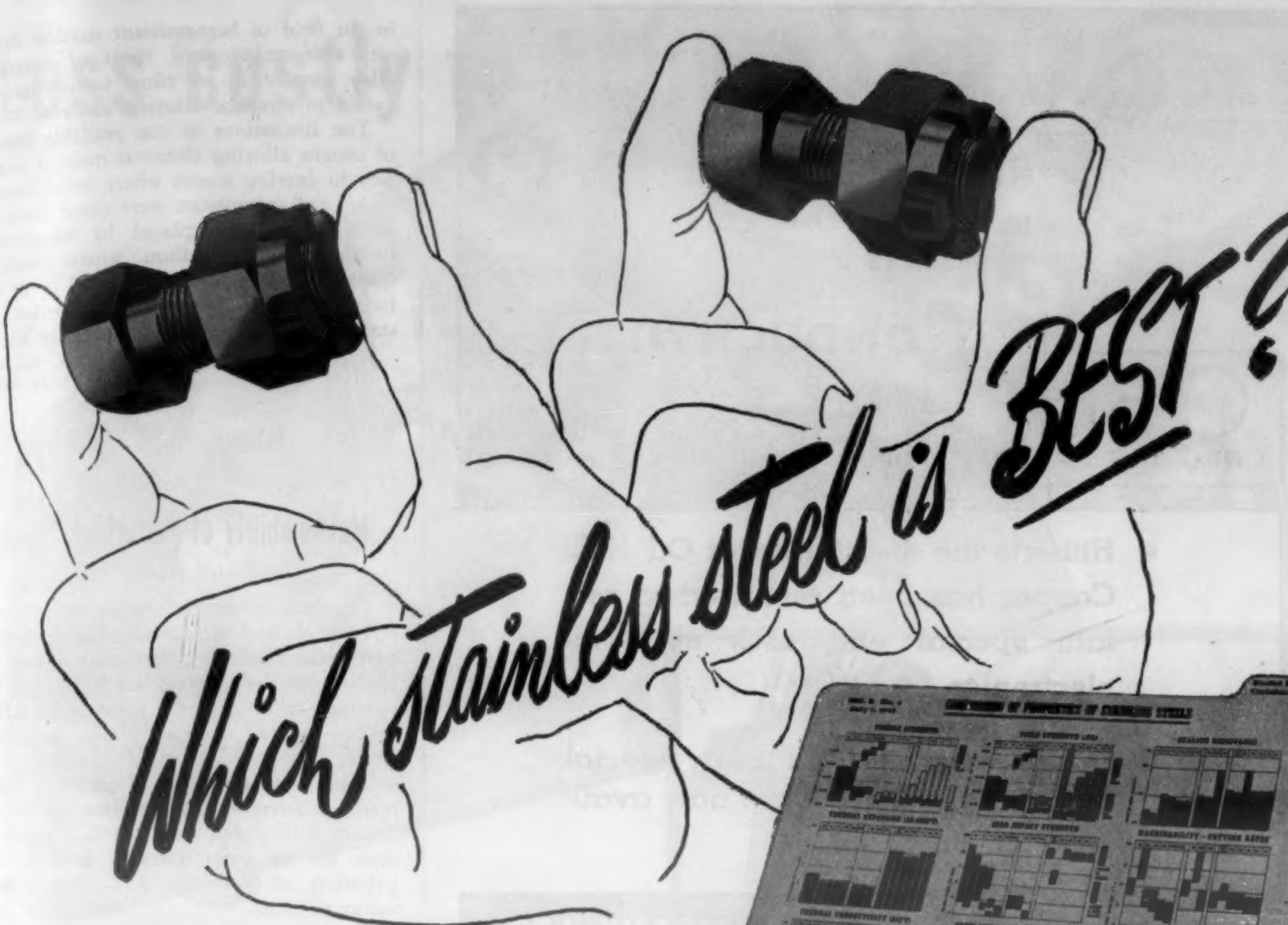
A number of the German steels are very similar to grades produced in the United States, but there are numerous deviations from what we consider normal composition and, in addition, there are numerous alloys which have not been commercially produced in this country.

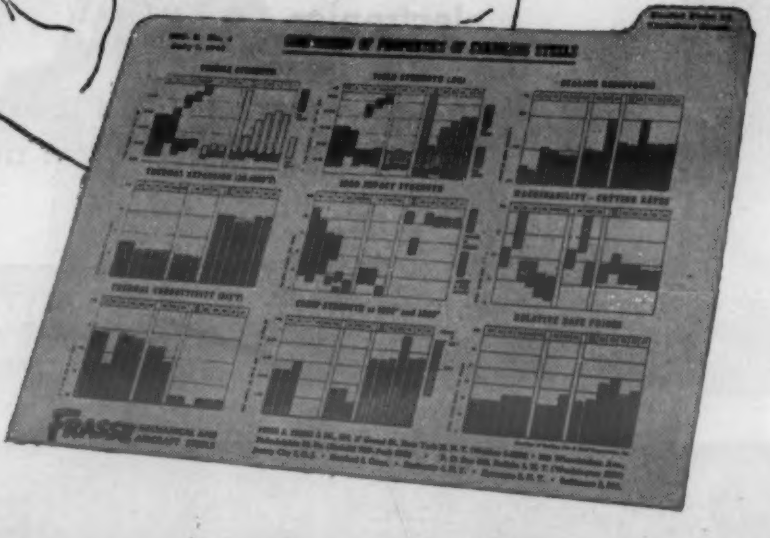
The turbine blade of the Junkers jet-plane was originally made from a low-alloy heat-treatable grade FK(D)M10 analyzing 0.25 carbon, 3 chromium, 0.4 tungsten, 0.4 molybdenum and 0.2% vanadium. Later the wheel was produced from a steel analyzing 0.30 to 0.40 carbon, 1 chromium and 0.20% vanadium, which was known as grade CM25.

One of the outstanding characteristics of the steels as a class is the extensive use of aluminum as an alloying element in the straight-chromium type of heat-resisting steels.

In the field of ordinary stainless steel applications the Germans did not develop anything of outstanding importance during World War II. In general, the research and development activities of Krupp

(Continued on page 788)





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MECHANICAL STEELS AND TUBING

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in the field of heat-resistant stainless steels were directed toward steels of lowering alloy content in an effort toward conservation of strategic alloying elements.

The limitations in the available supply of certain alloying elements made it necessary to develop grades where molybdenum, nickel and columbium were either not used or were largely replaced by manganese, titanium and vanadium where possible. Cobalt and columbium appeared to be no longer available for the production of stainless steels and high-temperature alloys.

—A. L. Feild. *Iron Age*, Vol. 156, Dec. 20, 1945, pp. 60-67.

Machinability of Sulfurized Steels

Condensed from "Steel"

Responding to the need for lowered direct costs and increasingly higher quality parts, manufacturers developed a host of special practices, secret methods, and inventions relating to the addition of sulfur in one form or another to alloy or carbon steels.

Typical of these are the two patented methods covering the addition of molybdenum sulfide and claiming as a result of their use an extraordinarily uniform distribution of desirable sized and shaped sulfur particles.

The advent of the war stimulated past efforts to improve the machinability of alloy steels. Sulfur introduced by means of an anhydrous sulfite has resulted in claims and reports of not only the usual improvement in machinability and finish of parts fabricated from steels so treated, but in a steel of more normal rolling characteristics as compared to other sulfur-bearing steels. A fourth advantage claimed is that a tool life greatly superior to that normally expected for an equivalent sulfur content may be experienced.

Recent experience in machining sulfite treated alloys has been quite favorable, both as compared with untreated and with stick sulfurized steels.

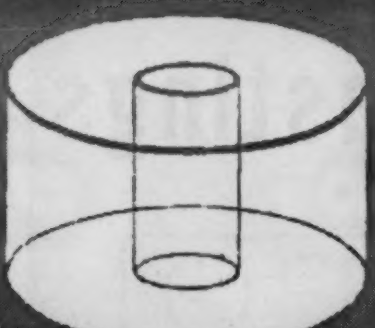
Sulfite-treated steel reduced the cycle from 33 to 27 sec. on one machine load of four bars. Subsequent production has eased the cycle somewhat with a gross increased production of parts of about 30%. Tool life, however, remains doubled and the overall efficiency has risen sharply.

A screw machine experimentation with sulfurized alloy brought out that like increases in tool life could be expected with sulfite-treated alloys over nonsulfurized steel in a typical NE analysis. This resulted in an indicated increase in past production of 38% and an increase in form tool life of over 300%; drill life improved over 100%.

Continued experimentation will be required before definite conclusions can be advanced, but these and similar preliminary reports of the increased tool life, machinability, or production realized with sulfite-treated alloys, and sulfurized alloys, indicate that a measurable contribution has been made toward improved machinability of the constructional alloy steels.

—H. M. Clarke. *Steel*, Vol. 117, Dec. 17, 1945, pp. 116, 119, 162.

MATERIALS AND DESIGN



NONMETALLIC MATERIALS

Design-uses of plastics, plywood, fibre, glass, rubber, ceramics, etc. as engineering materials. Composite metal-nonmetal combinations. New types and forms of nonmetallic materials.

New Plastics in Aviation

Condensed from "Aero Digest"

Four new plastics, *Plastipeel, Plastiform, Plastipaste,* and *Plastitool,* are now being extensively used by aircraft manufacturers. They were developed by L. C. Wilson, chief engineer for Duorite Plastic Industries at Culver City, Calif.

A vinyl-base material that resembles lacquer, *Plastipeel* is used as a protective covering for metals. It can be applied by dipping, brushing, or spraying.

It dries tack-free in 20 to 30 min. and gains its maximum strength in approximately 5 hr. Unless it is purposely cured with heat, it can be readily peeled from any surface with the fingernails.

Plastiform is a combined ceramic and thermoplastic, which is 100% reclaimable without additives. It has been used in making profile or Keller duplicating blocks, blueing blocks, master mockups, router fixtures, nesting fixtures, master checking fixtures, stretch press form blocks, forms for contact laminating, protective coverings for other materials, and molds for casting other plastics.

It can be melted in a steel or black iron double boiler, the outer container containing an oil bath and a thermostat which should maintain temperatures of 300 to 400 F.

Finished castings of this material can be sawed, sanded, drilled, and otherwise machined like hardwood. It can be polished with steel wool.

The third material, *Plastipaste,* is a thermosetting phenolic resin compounded with suitable fillers for high strength and low shrinkage. Because it weighs only about half as much as magnesium, it has been found especially useful in fabricating router fixtures, nesting fixtures, forms for contact laminating, and others.

It can be cured in 10 min. by use of a hot catalyst, or 6 to 8 hr. with a cold catalyst, the latter, however, producing the most desirable physical properties.

Plastipaste is essentially a troweling material because of its extreme viscosity, although it can be cast as a solid mold. It cannot be machined by all conventional methods, but it can be readily drilled or sawed with ordinary woodworking tools.

Distinguished by the fact that it has the greatest impact resistance of any plastic of this type currently known to exist, *Plastitool* is a cold-pour phenolic whose physical properties are attained without fillers. It has been used in making form blocks, dies, ornamental objects, and numerous small accessories.

Its strength characteristics depend on the quantities of catalyst that are added to the mix. It is cured in an oven for a period of 4 to 8 hr. at about 150 F.

—T. A. Dickinson. *Aero Digest,* Vol. 51, Dec. 1, 1945, pp. 73-74, 126.

Zircon as a Ceramic

Condensed from "The Bulletin of the American Ceramic Society"

Zircon, a zirconium silicate, has a specific gravity of 4.6 to 4.7, Mohs' hardness of 7.5, poor electrical conductivity, and extremely low magnetic susceptibility. Its average coefficient of linear expansion from 20 C to 1200 C is 45×10^{-7}, per degree C, placing it in the category of refractories very resistant to thermal shock. The system has a melting point of 2550 C (4622 F), with other molecular combinations melting at from 1705 C (3101 F) to 2430 C (4406 F).

Zircon is available to the ceramic industry as technical grade, with 64.5% ZrO_2; ceramic grade, with 66.5%; and electrical grade, with 67.1%. As a refractory, its characteristics include (1) high melting point and softening point (P.C.E. value approximately cone 42); (2) thermal conductivity of an order similar to fire clay but inferior to silicon carbide; (3) relatively low thermal expansion; (4) freedom from pronounced structural inversions, and (5) satisfactory abrasion resistance and striking resistance to certain molten metals and acidic chemicals, slags, and glasses.

Of major importance in the function and application of zircon refractories is (1) selection of proper types and proportion of grain and fines for optimum physical and thermal values; (2) choice of suitable green bonding agents; (3) determination of the nature and amount of fire bonding agents to retain maximum refractoriness and strength; (4) selection of suitable particle-size distribution and deflocculation agents for slip casting zircon ware; and (5) proper firing temperatures and schedules adapted to the end use of the refractory in question.

These refractories have been successful in metaphosphate manufacture, in the melting of aluminum, for laboratory ware, in

precious-metal melting and dental investment procedures, in centrifugal high-temperature alloy casting, and in experimental glass-melting furnaces. It has also been used as a core sand and mold facing in casting of intricate steel, brass, bronze, aluminum, and magnesium equipment.

For electrical-resistance heating appliances, zircon forms the major component of cements for strip and ring units, hot plates, cartridges, immersion heaters, etc. In the formulation of glasses, glazes and enamels, zircon contributes soluble zirconia, and acts as an opacifier. In special porcelains for spark-plugs, zircon has contributed valuable properties in connection with quartz inversions.

—N. R. Thielke & H. W. Jamison. *Bull. Am. Ceramic Soc.*, Vol. 24, Dec. 15, 1945, pp. 452-456.

Physical Properties of Mica

Condensed from "The Journal of Research of the National Bureau of Standards"

As the outgrowth of a military problem, an investigation of some physical properties of various kinds of mica was undertaken. Muscovite, phlogopite, biotite, ripidolite, and zinnwaldite were studied, using domestic and foreign material.

Linear thermal expansion was measured, the determinations being made in a direction perpendicular to the cleavage plane of the mica. Tremendous expansion was noted for some samples of phlogopite and biotite. Samples were studied at temperatures in the range from room temperature to 600 C (1100 F), and under 30 p.s.i. Four samples expanded from 50% to 166% when heated through this temperature range.

In general, the cooling curve lies above the heating curve. A phlogopite sample, measured under 1 p.s.i., and heated from room temperature to 600 C, showed the greatest expansion of the entire lot, 300% for the first run to 240% for the third run. Increase of the load to 30 p.s.i. for the fourth run reduced the total expansion to 50%.

These expansions are by far the greatest of any known solid material. Nearly all the muscovite samples showed the greatest increases in thickness after heat treatment at 800 C (1470 F). Increases were reported as up to 155%.

For the muscovite samples, color changed from clear to translucent or opaque, or from polychrome to metallic, upon heating to the temperatures given.

Since the chemical composition of all of the varieties of mica studied shows appreciable variation, they cannot be considered as pure materials, with fixed and reproducible properties. The physical properties studied depend upon chemical composition, the nature of the crystals, their magnitude and orientation, the way in which impurities enter the structure, heat treatment, etc.

At temperatures in the range 800 to 1000 C (1470 to 1830 F) many of the samples lose water of crystallization. The muscovite micas are erratic at these temperatures, due to dehydration. Phlogopite varieties, especially the light-colored ones, will withstand 800 C without appreciable dehydration. At 1200 C (2190 F) all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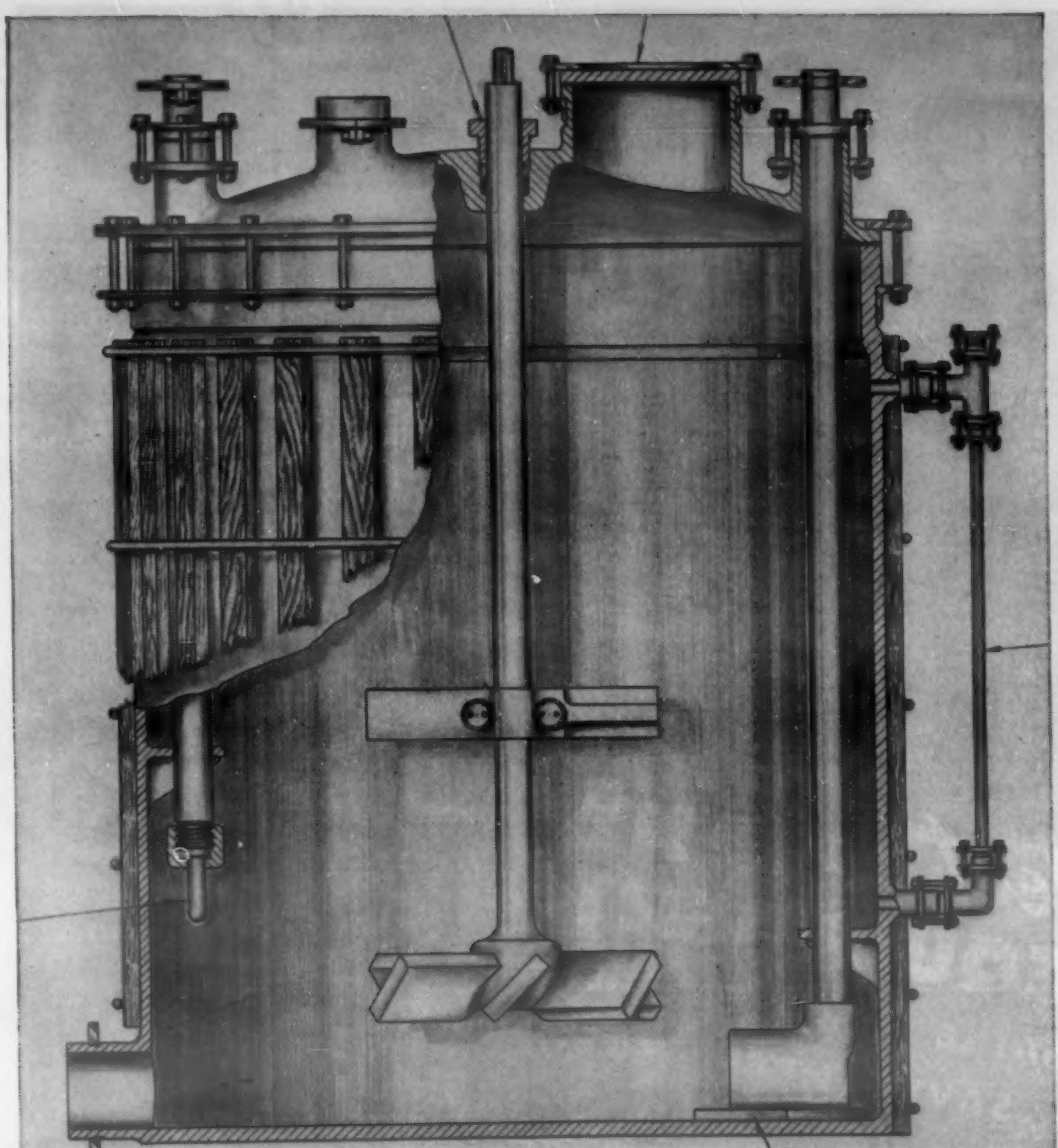


the micas blistered and were so changed as to be unsuitable for use.

Power factors of two phlogopite samples were considerably larger than those of two muscovite samples, and increased when heated to 600 C, while power factors of the latter showed little change.

Some of the phlogopite and biotite micas may have decided advantages for use in expanding elements in temperature-responsive devices.

—Peter Hindert & George Dickson. *J. Research Nat. Bur. Standards*, Vol. 35, Oct. 1945, pp. 309-353.

Chemical Resistance of Plastics

Condensed from "Plastics"

The resistance of organic plastics to chemical reagents shows wide variation, some being highly impervious to most chemicals, whereas others are readily compatible with a broad selection of organic solvents. With respect to acids, plastics compare favorably with the more common metals, strongly resisting attack.

Water is an effective solvent for some plastic materials, and a partial solvent for others. Plastics may be grouped as follows in regard to their comparative resistance to water:

Best resistance—Polystyrene, polyethylene, furane resins, polyvinyl chloride acetate, polyvinylidene chloride.

Good resistance—Phenol formaldehyde, polyesters, polymethyl methacrylate.

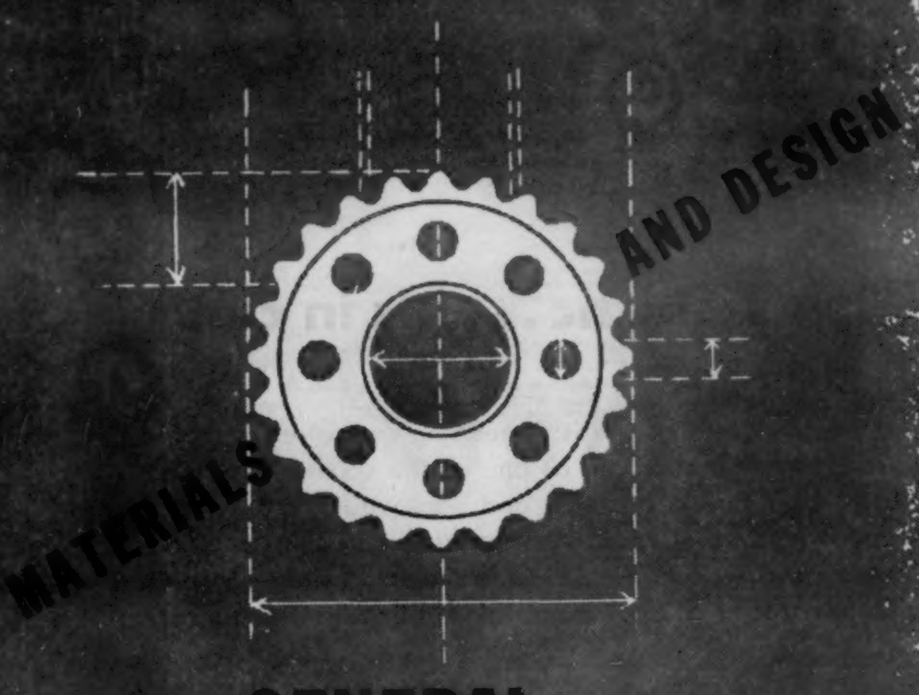
Fair resistance—Polyvinyl butyrals, urea and melamine, formaldehyde, cellulose acetate, cellulose nitrate, polyamides, ethylcellulose, cellulose acetate butyrate.

Organic solvents may be true solvents, partial solvents, or nonsolvents for the various plastics. Partial solvents may cause loss of strength or some swelling without causing solution. Some common plastics and their solvents are: *Cellulose nitrate*—acetone, ethyl acetate, butyl acetate; *cellulose acetate*—acetone, ethyl acetate, 70% ethylene dichloride, 30% methanol; *cellulose acetate-butyrate*—acetone, chloroform, ethyl acetate; *polystyrene*—styrene monomer, benzene, acetone, toluene; *polyvinyl butyral*—furfural, alcohol; *polymethyl methacrylate*—monomer of acrylic, ethylene dichloride, chloroform, glacial acetic acid; *polyvinyl chloride-acetate*—methyl ethyl ketone for 87/13 proportions, isophorone, mesityl oxide, cyclohexanone (for higher chloride content); *polyamides*—hot formic acid, phenol, resorcinol; *polyethylene*—hot xylene, benzene; *polyvinylidene chloride*—hot orthodichlorobenzene; *ethyl cellulose*—acetone, 80/20 benzene-alcohol.

When resistance to oil and grease is required, plastics of the nonrigid polyvinyl alcohol, polyvinyl chloride, and polyvinylidene chloride types are representative. Some of the synthetic rubbers are also useful for this purpose.

In general, plastics show good resistance to acids and alkalies. From the standpoint of acid resistance, chlorinated rubber, polyisobutylene, polyethylene, tetrafluoroethylene, polydichlorostyrene, chlorinated neoprene, polystyrene, polyvinylidene chloride, polyvinyl chloride and polyvinyl chloride-acetate are acceptable.

—John Delmonte. *Plastics*, Vol. 3, Nov. 1945, pp. 36-39, 129-133.



GENERAL PRODUCT DESIGN

Selection, applications and design of parts made by various fabricating methods or made of special materials. Properties and uses of finishes and coatings. Design and materials for specific products or fields. General engineering design trends or principles.

Materials for Motor Valves

Condensed from "Stahl und Eisen"

One of the most stressed parts, both mechanically and thermally, of a combustion motor is the outlet valve, especially in modern airplanes. The inlet valve operates under much cooler temperature. The material used for valves must possess, before all, good machinability, fluidity in casting, and also good weldability.

The heat-resisting materials for the outlet valve are now mostly cooled by making the valve shaft hollow, and sometimes also the valve disc, for enclosing sodium as cooling agent. The manufacture of such hollow valves is a fairly difficult operation.

The temperatures that outlet valves have to withstand have been measured in an air-cooled motor with 3000 to 6000 r.p.m. to be between 740 and 810 C (1360 and 1490 F), and in a water-cooled motor for 2000 r.p.m., 720 to 750 C (1330 to 1380 F). Sodium-cooling is most effective, with 40 to 50% of the hollow space filled with sodium in large, and 60% in small valves.

The motion of the moving hot valve throws the molten sodium to and fro and so conducts the interior heat to the valve shaft. Sodium proved superior to all other substances because of its low melting point, moderate vapor pressure at high temperatures, high heat conductivity, and low density. This made possible a reduction of the maximum temperature of the outlet valves up to 150 C.

Head and shaft of the valve are made of different materials, each best suited for the part. An austenitic steel is used first as carrier of the heat resistance on the shaft and on this is then welded a layer of hardenable steel or a hard alloy. Hardnesses of 500 to more than 600 Vickers are attained.

The gliding part of the valve stem is improved by cold-deformation or nitriding. The valve disc is improved on the seat by welding on a layer of a hard alloy of 1.2 to 1.5 carbon, 25 to 27 chromium, 60 to 65 cobalt, and 3 to 6% tungsten. The hardness attained is about 450 Vickers.

Lately, a somewhat softer alloy (Brightray) of 0.5 carbon, 1 manganese, 0.3 silicon, 20 chromium, 74% nickel, remainder Fe, with a hardness of 250 to 300 Vickers units, has been recommended. The bottom of the disc is protected either by a layer of Brightray or by a chromium-cobalt-tungsten hard alloy with a hardness at the seat of 485 and at the bottom of 420 Vickers units.

A simple chromium layer also offers protection against scaling. The chromium-rich layers are necessary for protection as the anti-knock, lead-containing motor fuels favor scaling.

Of hardenable steels with conversion temperatures above the operating temperatures of the valves, the following had practical importance: Nickel-chromium steels (0.12 to 0.35 carbon, 0.3 to 1.5 chromium, 3.5 to 5% nickel), high-speed steels, silicon-chromium steels (0.4 carbon, 4 silicon, 3% chromium), rust-proof chromium steels (0.4 to 1.5 carbon, 9 to 16% chromium) with or without additions of silicon, cobalt, tungsten, molybdenum or vanadium, singly or almost all together. Their disadvantage is reduction of mechanical strength at higher temperatures. Austenitic steels are superior in this respect. Those used are 0.2 to 1.2 carbon, 0.2 to 3.5 silicon, 0.4 to 1.5 manganese, 11 to 25 chromium, 7 to 62 nickel and 0 to 5% tungsten, with occasional additions of molybdenum, cobalt and also vanadium.

As materials for the seat rings, austenitic cast iron (3.0 to 3.4 carbon, 2.0 to 3.0 silicon, 10 to 12 manganese, 5 to 6% nickel), quenched from 1000 C (1830 F) and tempered at 500 C (930 F), with a Brinell hardness of 220 to 280 is used, as are aluminum-nickel-iron bronze and manganese-chromium steels.

The material for valve guides can be pearlitic cast iron, *e.g.* 3.4 carbon, 2.6 graphite, 1.6 silicon, 0.7 manganese, 0.5% phosphorus, Brinell hardness 300, which proved to be satisfactory even for outlet valves. However, the predominant material for both inlet and outlet valves is phosphor bronze, which beside high tin content can also have additions of nickel and lead (84 to 89 copper, 12 to 9 tin, 3.5 to 0 nickel, 2.5 to 0 lead and 0.4 to 0.7% phosphorus; Brinell hardness 110 to 125.

—H. Cornelius. *Stahl u. Eisen*, Vol. 64, July 6, 1944, pp. 433-438; July 13, 1944, pp. 453-458.

Rubber Machine Parts

Condensed from "Machine Design"

Five basic types of synthetic rubber are used for machine parts.

Buna S is similar in processing and performance to natural rubber. It can be vulcanized with sulfur and cured to hard rubber. Its resistance to deterioration in air at room and elevated temperatures is considerably better than that of natural rubber. It is widely used for electrical cable insulation as a result of its excellent electrical properties. Buna S is also suitable for water pump seals and gaskets, but not for oil equipment.

Buna N resembles Buna S in regard to vulcanizing and curing properties. It has outstanding resistance to oil and good break-away properties in contact with metals. Buna N is satisfactory for oil and gasoline hose, packings, gaskets, rubber covered rolls, valve inserts, molded dust seals, diaphragms for hydraulic gear shifts, hydraulic lines, and vibration dampeners.

Neoprene is a general purpose synthetic rubber with good resistance to chemicals and oils and excellent resistance to heat, air and light. Although its electrical properties are lower than those of natural rubber, it is used for the outer sheathing of electrical insulation due to its flame resistance. Typical applications of Neoprene include oil resistant hose, belting, gaskets, fuel cells, solid truck tires, airplane tires, printing rollers, and airplane hull and wing caulking.

The processing of Butyl is similar to that of natural rubber, but a longer curing time is required and it cannot be vulcanized to hard rubber. The physical properties are lower than those of natural rubber, but the general resistance to deterioration is good. Its resistance to oxidation and acid are very good. Butyl is used in acid handling equipment, inner tubes, and other applications where its impermeability to gases and resistance to chemicals and oxidation are important.

Thiokol has excellent resistance to oils, greases, solvents, ozone, sunlight, and natural aging. Its resistance to aromatic hydrocarbons and aromatic blended gasolines is better than that of natural rubber or any of the other synthetics. It is used where resistance to deterioration is more important than physical properties. Typical applications include paint spray and solvent hoses, selector valve rings, diaphragms, cable covers and tank linings.

—*Machine Design*, Vol. 17, Dec. 1945, pp. 116-119.

Super Opaque Titanium Enamels

Condensed from "Finish"

To the enameler, who is constantly seeking means of improving the reflectance of cover coat enamels, titanium oxide (anatase) with its high index of refraction has long been of interest as an opacifier, and investigators have reported on various types of enamels in which titanium oxide was a major constituent.

Dr. B. Niklewski in a recent communication recommended a titanium oxide-bearing enamel, which was found to have high reflectance, good texture and gloss, and fair color. The purpose of this investigation was to study this enamel to determine its suitability.

The enamel submitted was found to have 80% reflectance at 25 grams per sq. ft. It was discovered that the incorporation of boric oxide was harmful to both color and gloss. Potassium oxide and alumina tended to produce matte surfaces. Cryolite was found to be a better flux than fluorspar or sodium silicofluoride. The fluorine content must be low for good gloss.

Calcium compound and whiting in particular improved the color of the enamel, and a high zinc oxide content was necessary for color purity and high opacity.

Thorough mixing of the frit batch was necessary to prevent the titanium oxide from balling up and forming seeds in the glass. Oversmelting resulted in reduced opacity and poor color. Undersmelting was harmful to gloss and texture. It was necessary to maintain an oxidizing atmosphere during smelting operation.

The surface of this enamel was not resistant to attack by 10% citric acid, but its solubility resistance as determined by E.U.M.C. test was very good.

The following chart gives the comparison between Dr. Niklewski's composition and the one developed by the authors:

Frit Compositions		
Feldspar	4.2	4.5
Quartz	25.1	25.3
Soda Ash	23.2	24.2
Sodium Nitrate	2.3	2.4
Whiting	—	3.4
Zinc Oxide	21.6	19.5
Cryolite	2.5	2.6
Sodium Antimonate	.8	.8
Titanium Oxide	16.9	17.2
Magnesium Carbonate	3.4	—

—C. M. Andrews & A. I. Andrews, *Finish*, Vol. 3, Jan. 1946, pp. 17-21, 74.

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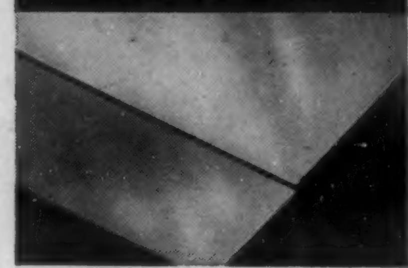
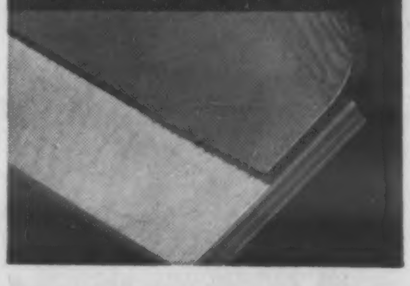


RUBBER TO PLASTIC



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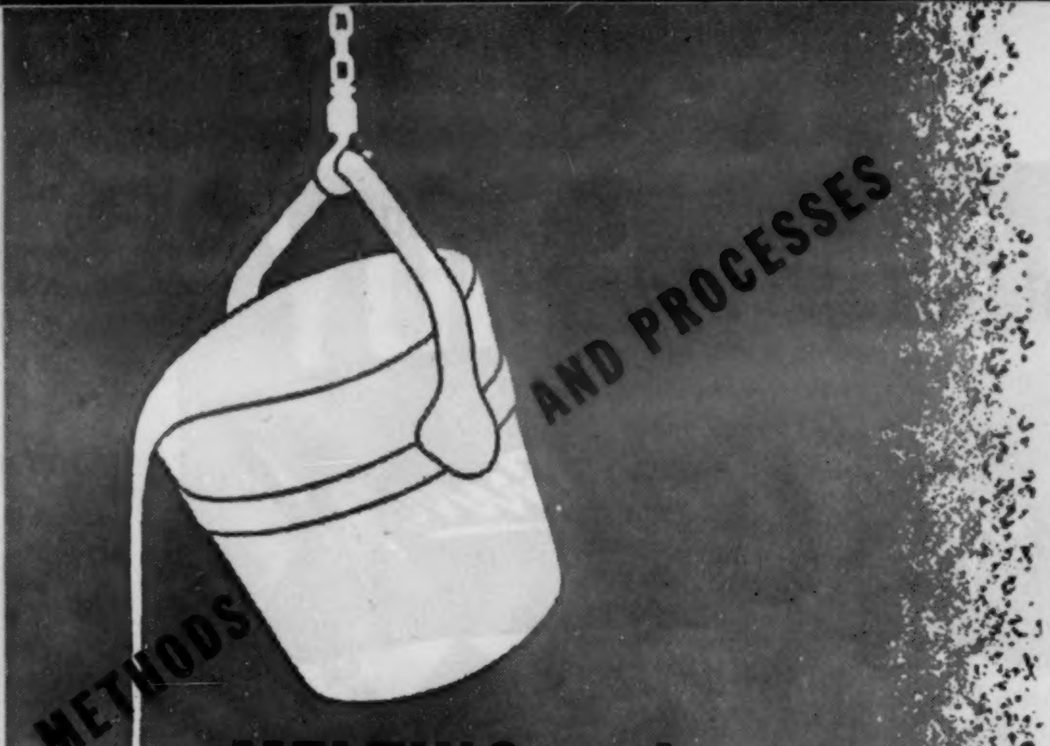

MELTING and CASTING

Melting, alloying, refining and casting methods, furnaces and machines. Iron and steel making, nonferrous metal production, foundry practice and equipment. Die casting, permanent mold casting, precision casting, etc. Refractories, control equipment and accessories for melting furnaces.

Feeding Metal to Molds

Condensed from "The Foundry Trade Journal"

Volume changes that occur in liquid steel before and during solidification are rather pronounced. Obviously a casting temperature higher than that at which freezing commences must be used, and this increases the amount of liquid shrinkage. In practice it has been found that a figure of 6% is sufficiently reliable to be used for total liquid shrinkage.

Liquid metal must be supplied to the solidifying casting to compensate for liquid shrinkage. This metal is supplied by the feeder heads into the casting. Existing methods are three types of combinations of these three types of forces, *i.e.*, gravity, atmospheric pressure, and centrifugal pressure developed in rotating mold. It would appear essential to introduce into the feeder head a sufficient amount of heat so that the head can retain its fluidity much longer than is the usual practice.

The authors' new method consists of casting metal in molds having one or more feeder heads in which there is introduced into the feeder head a charge of a certain material producing gas. Additionally there can be introduced an exothermic composition such as a mixture of iron oxide and aluminum. The gas and heat evolution compound is called "Kayell" compound by the authors.

The gas compound hangs 1 in. from the top of the head by a small wire attached to a core print. When the head is completely filled with liquid steel, the gas compound is surrounded on all sides by liquid metal. The head is almost immediately enclosed by thin skin formed by the sudden chilling action of mold.

Shortly, the exothermic reaction begins, and gas and heat are evolved. The heat is absorbed by the metal in the immediate vicinity, and the gas evolved is trapped in the thin shell of metal enclosing the head.

In steel foundries using normal types of gravity feeding heads (with open tops or as blind heads) the normal yield is in the order of 50%. If any higher average yield than this is obtained, it is generally at the expense of soundness in the castings.

The "swirlgate head" (developed by Hopkinsons, Ltd. and the English Steel Corp., Ltd.) and the "atmospheric head," developed by Williams, are recent improvements. Centrifugal casting with vertical axis machines utilizing centrifugal force to secure high liquid pressure to compensate for shrinkage has the same object. However, none of the methods previously developed results in a yield approaching the theoretical possible (*i.e.* about 90%). With gas-pressure heads, yields of 80 to 95% can be regularly obtained with full compensation for liquid shrinkage.

—S. T. Jazwinski & S. L. Finch. *Foundry Trade J.*, Vol. 77, Nov. 29, 1945, pp. 269-274; Dec. 6, 1945, pp. 293-303.

Malleable Sand Control

Condensed from "American Foundryman"

The sand handling equipment and sand control methods used in a large mechanized foundry show interesting details. The castings made are automotive and gun parts ranging from a few ounces to 65 lb. in weight. Synthetically bonded molding sands are used in continuous molding systems.

Raw materials are stored in a separate

IMPROVING the Machinability of Heat-Treated Parts by WHEELABRATING

By J. R. McAllister, Plant Metallurgist
Syracuse Heat Treating Co., Syracuse, N. Y.

At the Syracuse Heat Treating Company, Syracuse, New York, one of the leading Eastern heat treating concerns, three Wheelabrator Tumblasts, a 15" x 20", a 20" x 27" and a 27" x 36", are employed to handle the complete cleaning of heat treated parts. With these machines they are equipped to process metal pieces weighing from a few ounces to over 75 pounds apiece.

Today, more and more companies in the various metal working industries are specifying heat treatments giving specific micro-structures and hardness requirements, but too few are giving the proper thought to surface condition both before machining and before final finishing operations, such as grinding, plating, coloring or polishing. There can be considerable saving of both precious time and money if the proper method of surface preparation is employed for the various finished conditions.

Forging Scale Usually of a Compound Nature

Let us take, for instance, rough forgings that have been properly normalized and annealed for their particular machinability problem. Naturally, as the slug of steel is heated in ovens at the forging plant prior to forming under the hammer, it oxidizes due to the relatively high temperatures needed to condition the steel for hammering. Plus having this scale formed by the oxidation of the metal, it can be noted under the microscope that a large percentage of the surface has been burned away by the oxygen in the surrounding air. The so-called forging scale formed under these conditions is usually of a compound nature having a layer of rather tight scale covered by loose or "feather" scale. The "tight" inner scale is formed in the heating furnaces under the hammer and the loose "feather" is formed on cooling after the piece has been forged into shape. After the forging is cold, it is sent to the heat treater, who then takes his turn at adding and subtracting to the scale condition of the piece. Some of the loose forging scale will drop off while handling from one department to another and more will become free in the heat treating furnace, but chances are that the furnace heat will replace a good share of this loose scale because atmospheres are not generally watched too closely on this rough grade of work.

The Problem of Machining

Now that the forging and heat treating operations are complete and we have a supply of scale which is very hard and brittle, and decarburization which is very soft and weak, our problem is to get a tool to make an even and uniform cut along the surface. This is not a simple problem with the material in this condition. The tool will often times get under way in a normal maner in the soft matrix of decarburization and suddenly hit a hard spot of scale. The easiest thing for the tool to do under these conditions is to break and sometimes cause a many-thousand-dollar shutdown.

There are two major methods of eliminating this condition before machining operations are started. One is pickling and the other is some method of blasting the work with sand, steel grit, or steel shot. The pickling method is being used less and less by commercial heat treaters and forgers because of the danger of pitting the work too deeply so it cannot be cleaned up and also because of the general messiness of the operation.

Removing Scale Down to Virgin Metal

With the use of Wheelabrator Airless speed cleaning machines the removal of heat treat scale is a simple matter because the hard hitting steel abrasive quickly removes the baked-on-scale right down to the virgin metal. Every nook and cranny of the part is completely scoured until every last vestige of scale is removed.

The Wheelabrator method of cleaning is also very effective for removing heat treating scale from machined parts or castings before grinding, plating, coloring and polishing. When cleaning before grinding, the use of a medium sized grit or shot will leave the surface bright and smooth, thus keeping the grinding wheels from loading up with scale and dirt. It is also found that a much larger percentage of work can be ground between wheel trimming operations if a clean scale-free surface is used.

The use of grit blasting for surface preparation of metal to be painted or plated is advisable because the smooth surface is broken up by the force and sharp points of the grit.

American
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building where they can be handled by an overhead crane and a clamshell bucket. This building also houses equipment for core sand mixing and seacoal crushing.

Local bank sands are used and are dried from moisture contents as high as 9% to 0.2%. This permits very close control of the water contents of the core mixtures. Core sand is prepared in mixers of kneading type. All dry ingredients are weighed and wet ingredients measured by volume. They are mixed 1 min. dry and 8 min. wet.

The molding sand preparation and handling is done in four continuous systems, each serving from 10 to 34 molding stations. Some of the systems supply both facing and backing sands. Continuous type mixers are used in a conventional arrangement. Clay additions are made at the mixer as a slurry.

Two tempering bins permit the sand to temper for at least 30 min., and then it is put through a squirrel cage aerator before going to the molders' stations. Molding is performed on jolt-squeeze machines. A conveyor takes the molds to the pouring station, then through a cooling hood to the vibrating shakeout screen.

The shakeout sand is put through a cooler and magnetic separator before it is returned for re-use. The cooling unit is believed to be very important in maintaining close control.

Since the core mixtures used replenish most of the sand losses in the system, the mixtures must be made not only to produce good cores and castings, but also to provide the proper grain when the burned-out core becomes a part of the molding sand.

—J. J. Clark. *Am. Foundryman*, Vol. 8, Nov. 1945, pp. 49-56.

Investigation of Cupola Charge Material

Condensed from "The Foundry Trade Journal"

It was felt that if the combustion and metallurgical reactions in a fully charged cupola could suddenly be stopped and samples from different parts of the charges could simultaneously be removed, the composition and condition of these samples would provide at least some of the information needed to study cupola behavior. To stop the normal cupola reactions and to cool the burden before removing the samples, it was decided to quench by simultaneously shutting off the blast and pouring in water on top of the burden through the charging door. The charge can be rendered inert by water cooling in less than 40 min.

Some of the authors' observations are summarized as follows: (1) However carefully the charge materials are placed in a cupola in relation to one another, their original relative position is not maintained during the descent of the charge; (2) shape and size of the metallic pieces in the charge are dominant factors in governing their manner of descent; (3) rate of complete melting of the different metallic constituents is mainly governed by their shape and weight as well as their relative melting temperature.

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(4) Metallic constituents that require a longer time to melt may not be melted completely until they have descended into the coke bed to considerable depth; (5) coke is progressively reduced in size from top to bottom of the shaft, both bed and charge coke; (6) weight of coke contained in different heights of the cupola was found to be increased as the charge moves downwards.

(7) Reduction in coke size in the bed proper is not uniform across a horizontal plane, the coke found in the center being reduced most; (8) extent of the slag ledge or bridge formed above the tuyere level is a main factor altering the line of flow of materials through the cupola as the day's heat proceeds.

(9) Carbon content of steel test-bars increases very slightly in their downward travel when solid, but on commencement of melting the carbon absorption becomes much more rapid; (10) carbon absorption by the melting steel takes place chiefly on the surface, the center of the steel pieces remaining practically unaltered; the highest carbon content found in a solidified metal drop was 1.2%; (11) some of the carbon picked up by the steel remains graphitic in nature.

(12) Steel contained in the charge picks up sulfur rapidly on its surface shortly after its introduction into the cupola, but on descending, some of the sulfur seems to be given off again.

—N. E. Rambush & G. B. Taylor. *Foundry Trade J.*, Vol. 77, Nov. 8, 1945, pp. 197-204; Nov. 15, 1945, pp. 229-235.

Measurement and Recording of Rolling Pressures

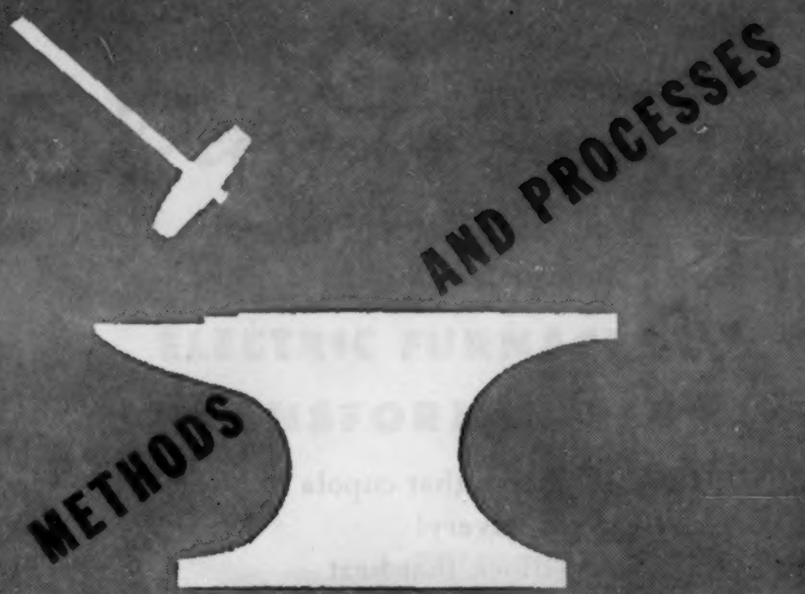
Condensed from "Stahl und Eisen"

An instrument (called Eltas caliper) has been produced for rolling mills that measures the rolling pressure in the stand by the extension of the roll housing. The measuring device consists of a measuring rod about 400 mm. length and arranged in the neutral axis of the stand. As the stresses in a roll stand never exceed the proportional limit, the elongation of the measuring rod is always proportional to the rolling pressure. The elongation should be at least 20 microns.

The measuring rod acts on a movable piece of iron between two coils through which alternating current passes. In the zero position (no load) both inductances are alike and no current flows through a galvanometer in a bridge arrangement of the coils. Under pressure the iron anchor is slightly moved and changes the inductances so that a current flows through the galvanometer, which also is proportional to the rolling pressure.

The instrument can be used also for continuous supervision of rolling pressure, counting of number of passes, supervision of the uniformity of the material in hot and cold rolling, and can be connected to alarm signals in case of any abnormal condition in the material or rolling process.

—N. DeBall. *Stahl u. Eisen*, Vol. 64, Nov. 9, 1944, pp. 716-720.



FABRICATION and TREATMENT

Machining, forging, forming, heat treating and heating, welding and joining, cleaning and finishing of solid materials. Methods, equipment, auxiliaries and control instruments for processing metals and nonmetals and for product fabrication.

Fabricating High-Strength Steel

Condensed from "Steel Processing"

U.S.S. Cor-Ten, which was introduced as a high strength low alloy steel in 1934, has a yield point of 50,000 p.s.i. and possesses exceptional workability and ductility. Experienced steel fabricators will have no difficulty in establishing procedures that will suit their equipment and the particular job at hand, in spite of the differences in fabrication behavior between U.S.S. Cor-Ten and structural carbon steel.

U.S.S. Cor-Ten can be hot formed with a minimum possibility of air-hardening and with negligible quench effects from cold die surfaces. Most satisfactory results are obtained by hot pressing at temperatures between 1500 F and 1600 F at the dies.

Although a greater unit force is required to produce a permanent set in U.S.S. Cor-Ten than in structural carbon steel, the total forming pressure is often no greater because the high strength steel is generally used in thinner sections. The technique of cold forming consists in making provision for more liberal bend radius, increased die clearance and more spring-back of the bend.

Shearing may require tighter or more secure clamping because the metal tends to pull more than carbon steels. Punching requires up to 20% greater forces for material of equal thickness. Fabricating suggestions for coping are similar to those considered good practice for structural carbon steel.

About 25% more power is required for sawing, milling and drilling operations, and speeds should be cut about one-third. Gas cutting may be freely performed with somewhat less affect on the metal.

U.S.S. Cor-Ten may be galvanized satisfactorily, but special cleaning precautions are recommended for hot-rolled steel. Sulfuric pickling, followed by water rinses and a hydrochloric dip, should precede the hot dip galvanizing.

Wartime operations under the most difficult conditions proved the soundness of lightweight design and construction. Loads far above rated capacities were handled with a minimum amount of repairs. Equipment was subjected to long hauls, inexperienced handling and a general lack of careful maintenance. Despite this abuse, high strength steel construction has proved its worth repeatedly in every field where it has been employed to reduce weight and minimize corrosion.

—C. E. Loos. *Steel Processing*, Vol. 31, Dec. 1945, pp. 755-759.

Drawing Thin Brass Shells

Condensed from "Machinery"

When the production of 20-mm. steel cartridge cases was discontinued, millions of coined cups were salvaged by drawing into stabilizer and flare tubes. The original head thickness of 0.310 to 0.330 in. was reduced to 0.070 to 0.085 in. by heading the closed end in a die to form a flange which was later trimmed off.

Only four drawing operations were required to transform the 1 1/16-in. high cups into 5⅜-in. high shells. There was 40 to 50% reduction in each draw. Tungsten carbide drawing rings were used.

The flare tubes were annealed at 1250 F after cupping and after the second and third draws; the stabilizer tubes were annealed only after cupping and the second draw. The drawn shells of SAE 1025 had higher mechanical properties than did cartridge cases made from the same material. Typical values were 100,000 p.s.i. tensile strength, 95,000 p.s.i. yield point and 9.5% elongation.

With thicknesses as little as 0.036 in., it was impossible to strip the drawn shells from the punches with mechanical strippers. The hydraulic stripping means ensured the removal without damage while the press was operating at 32 strokes per min.

Oil was delivered under pressure through the center of the punch to the bottom of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the shell. The pressure caused the shell to expand slightly away from the punch until the shell was free enough for the pressure to force it off. If the shell was not removed, a safety trip stopped the press.

A very light grade oil was supplied at 25 p.s.i. from a central pumping station. The maximum pressure depended on the adherence of the work piece to the punch but was as high as 10,000 p.s.i. A ball check was provided to prevent back pressures into the supply line which originally broke several die sets. The loss of oil was negligible, as it was returned to a reservoir.

—H. F. Hild. *Machinery*, Vol. 52, Dec. 1945, pp. 147-153.

A.C. Arc Welding

Condensed from "Southern Machinery & Metals"

Advantages of a.c. welding are widely recognized, especially for work that requires currents of 100 amp. or more. The absence of troublesome arc blow, the fast easy welding, low power consumption and low maintenance have been proved by thousands of installations. Where records have been kept of a.c. alongside d.c. welders, the former is found superior.

A wide variety of heavily-coated a.c. electrodes is available for every application—for vertical and overhead positions, for flat and horizontal welding, for light gage work in vertical and overhead positions, for flat and horizontal work, for high tensile steel, for cast iron, and for hard surfacing.

The operator is not troubled by magnetic arc blow, the molten pool is easier to control, and a steady, uniform travel speed is more easily maintained.

In d.c. welding arc blow can slow down speed by 15 to 20%. The blow increases rapidly with increase in current. Higher currents and larger electrodes can be used with a.c.

In making fillet welds in the horizontal position, by increasing the current and changing from $^3/_{16}$ to ¼ in. diam. electrodes, the rate of deposition can be increased by as much as 100%. For armor plate, operators with a.c. have used ½-in. electrodes.

In making $^5/_{16}$-in. horizontal fillet welds, one shop was producing 11 linear feet of welded joints per hr. with $^3/_{16}$-in. electrode and d.c. welders. After changing to a.c., the current was increased so that ¼-in. electrodes produced 15 ft. per hr., or 36% faster. A large fabricator of structural steel over an eight-year period finds that a.c. welders have increased speed by 15%.

In general, maintenance welding operators have stepped up welding speeds as much as 90% by shifting to a.c. welders. In deep fillet welding, the a.c. technique provides for deeper penetration of the weld metal into the joints, making a stronger bond.

The smooth uniform appearance of a.c. welds commends them and it takes less skill to perform the welding, with new hands more quickly trained. The danger of porosity, slag inclusion and undercutting is greatly reduced.

The following are 11 applications where a.c. welding serves best: deep fillet, stainless steel, light gage or intricate work, heavy steel stock, cast iron, shipways, subassembly, bases and frames, maintenance and repair, submerged melt, or automatic welding and highest quality pressure vessels.

—*Southern Machinery & Metals*, Vol. 1, Nov. 1945, pp. 7-12, 24-26.

Lubricants for Drawing Magnesium

Condensed from "Steel"

Many of the difficulties in drawing magnesium are tied up with the brittleness of the close-packed hexagonal crystalline form. As the temperature of the metal is raised, however, the deformation properties of the metal are greatly improved and at temperatures of 450 to 700 F the metal may be more severely worked than can most other metals at room temperature. Temperatures above 750 F should be avoided.

This situation, which makes hot forming of magnesium necessary, results in basic differences in lubrication problems from those encountered in cold forming of other metals.

Desirable properties of a lubricant for drawing magnesium are: (1) Ease of application, (2) good lubricating qualities, (3) ability to withstand temperatures up to 700 F, (4) chemical inertness, (5) quality of burning off without leaving a residue that is difficult to remove, and (6) lack of toxicity.

Most widely used component of lubricants for drawing magnesium is graphite, because of the resistance of this material to high temperatures and its innate lubricating qualities. Dow Chemical Co. engineers have found colloidal graphite suspended in a volatile solvent to be very good. This is sprayed on the sheet with a conventional spray gun. Acheson colloidal graphite Type 2404 for sheet (used in the proportion of 1 part to 50 parts of carbon tetrachloride) also can be employed.

Another method of using graphite is with a suspension of 20% flake graphite in tallow or in tallow and mineral oil mixture. In this case, it is suggested that this be applied by buffing on die surfaces rather than to the work. Flake graphite in a volatile solvent has also been suggested.

In using graphite it is desirable to clean the die occasionally and to rub some graphitized grease on the working surfaces by means of an asbestos pad.

It is very important to clean the work as soon as possible after using graphite lubricants. In general, Dow Chemical Co. suggests use of oiled rather than chromium pickled surfaces if graphite is used since cleaning is facilitated.

Other suggested lubricants include a mixture of high flash point oil consisting of asphaltic still residue and black oil, with 0.75 lb. of mica per gal.; Lennox soap solution and a good brand of heavy machine oil for use on the dies.

Many workers suggest the use of mild steel for tools rather than hardened steel. It is important to maintain a high polish on the tools.

Punches for drawing magnesium are made of steel, aluminum, cast iron, zinc, and even magnesium alloys.

—Samuel Spring. *Steel*, Vol. 117, Dec. 31, 1945, pp. 64, 66.

Die Cast or Built Up?

Condensed from "Die Casting"

Many designers of metal products, needed in moderate to large quantities, though aware that die castings fit certain needs, are prone to rely upon assemblies built up chiefly from sheet metal and from bar stock, especially stampings and elements turned out on the screw machine. There are many cases where die castings are not only cheaper, but are a superior product.

Construction of components by combining stamped and screw machine products generally involves fabricating numerous parts, all of which must be handled separately sooner or later and fastened into an assembly, usually by riveting, welding, staking, application of screws or like processes, often requiring machines or special tools.

Fabrication is rapid and low cost materials can be used, but handling and assembly costs often run high and tooling charges may exceed those for die castings. The final product is often inferior in appearance and perhaps lacks desirable features easily incorporated into die castings.

Take a certain clock frame. All bearing and other bosses are formed with height and center distances held within quite close limits. Holes are cored at or very close to size and only the simplest machining, such as reaming or spot facing, is required. After gears and working parts are applied, the ends of the integrally cast stepped spacer tubes are spun over or joined by screws, and the assembly is completed.

If the clock frame had been made of stamped parts and screw machine products, not less than 20 parts would be needed, as numerous bosses would have to be made as separate pieces and staked or otherwise assembled. Plates would require blanking, piercing, forming and hole reaming and screw machine parts would be needed to space the plates apart. If brass were used material costs would be high and scrap would be formed.

Another part was built up originally by blanking and forming aluminum sheet parts and welding them together at a cost of $5 per assembly. Later the unit was die cast in the same shape at about one-tenth this cost.

Take a phonograph record changer, involving a gear combined with two cams, a hub and several bosses for mating parts. Die casting is the answer. A similar blank could be sand cast or produced in a plaster mold, but much machining would be needed. But with the die casting, the only machining is to ream certain holes and do spot facing. Cams and gear teeth are die cast to size and the holes precisely cored.

—*Die Casting*, Vol. 3, Dec. 1945, pp. 38-40, 59-60.

(More Digests on page 817)

Automatic Roto Shaving

Condensed from "The Iron Age"

Several years ago, rotomilling was introduced to replace turning. The method consisted of rotating the work in between one or more pairs of milling cutters. Although the accuracy and speed of production were high, the size and expense of the equipment limited its application.

National Broach have now announced another new process, roto shaving, a logical outcome of rotomilling. This equipment is compact, reasonably priced and highly efficient. Similar in principle to the gear shaving process, it is designed for finish machining operations on all kinds of cylindrical, flanged and conical parts. The cutters and work both rotate.

The cutters resemble specially formed, fine pitch milling cutters with the number of cutters determined by the number of surfaces to be finished in one setting. With a stock removal of 0.010 in. on flanges or 0.020 in. on diameters, rough machined parts may be finished to grinding tolerances with a fine smooth surface at least equivalent to that obtained in green grinding.

The process lends itself to an almost infinite variety of combinations and simultaneously shaving a diameter with adjacent shoulders or a bore with adjacent face square. Machines may be made up as single spindle units or combined into special multiple spindle arrangements.

Typical applications include an automobile transmission clutch gear which is roto shaved on two diameters and adjacent shoulders and a ring gear where the bore and back face are finished in a single operation.

—Walter Praeg. *Iron Age*, Vol. 156, Dec. 27, 1945, pp. 56-57.

Electroforged Gratings

Condensed from "The Welding Engineer"

"Electro-forging" is what the author calls a novel process by which ship gratings are manufactured. Gratings are used in many places about warships, such as around 20-mm. gun mounts, engine and fire rooms, under submarine periscopes, for ladder treads, etc. The new type of manufacture was accomplished at Mare Island Navy Yard. Formerly, it was made by piece-by-piece arc welded fabrication.

The author devised fixtures, dies and other equipment that would permit its manufacture on a spot-welding machine, which has reduced labor to about 20% of formerly and has saved arc welding electrodes. Correct gratings for every purpose can be obtained by this method.

Basically, the grating consists of parallel flat brass bars, placed on edge and equally spaced, with round rods serving as the cross-tying members. The rods are pressure welded or electro-forged into the top edges of the bars. The forging is done on a conventional spot welder using dies instead of electrodes.

The dies should be of sufficient length to cover the number of welds that the

machine is able to handle at one operation. They should be made of a copper alloy having a high degree of conductivity and a high annealing point, and should be efficiently water-cooled.

A flat bar, 1/8 in. by 1 in. and a round rod of 1/4-in. diam. need about 4,500 amp. and 600 lb. pressure per weld and about 3 sec. heat time. If the dies are made to cover five flat bars, there will be five welds at each machine operation. Thus, the machine should be set at 22,000 amp. and 3,000 lb. pressure and about 3 sec. heat time.

Normally, the rod will be pressed into the bar just before the heat cuts off. The pressure setting is particularly critical. Too much will force the rod into the bar before the temperature of the two pieces is raised to the welding point. Too low a pressure fails to keep forging the rod into the flat bars as the heating progresses, and there will be a drip of metal that is too hot for some of the welds.

The rod should be pressed flush with the top edge of the bar. At each junction point excess metal squeezes out to form a small saddle, thus creating welds of large cross-sectional area.

The unwelded section of the rod must be free to bend from its sunken position up to the edge of the next flat bar as the dies are forging the rod into place. The bend straightens out as the grating is moved to the next welding position and another section of rod is forged into union with the bar.

—A. J. Randolph. *Welding Engineer*, Vol. 30, Dec. 1945, pp. 50, 51.

Metal Spinning

Condensed from "Modern Machine Shop"

Where circular drawn or formed pieces made from sheet metal are required in thousands, no method of production can compete from standpoint of speed and economy with stamping. But where experimental samples or pieces from 12 to 200 are wanted, spinning is the most economical. Spinning used to be regarded as a rather crude method of metal forming, but in recent years objects can be spun to close tolerances and modern skills are required.

Experienced spinners are able to approach quite closely the accuracy in complicated contours of the die-pressers. Spinning is particularly adapted for thin work over 48 in. in diam. The operation is performed on a lathe similar to a woodworkers' lathe.

For thin or small work, a simple forming lever is pressed against the workpiece. When the material is large or thick, a double lever is used.

With a double lever the workman's left hand applies pressure on the tool (a round knob at the work face) by pulling the lever toward him and his right hand moves the tool radially on the chuck. The spinning tool is usually steel for spinning non-

(Continued on page 822)

ferrous metals, and brass for spinning steel. Hardened steel rollers are sometimes used.

The tip of the tool is shaped according to the type of contour being spun. A contour that has long sweeping curves is spun with a flat-sided tool; a contour with sharp breaks needs a pointed tool to tuck the material into the corners.

A sharp edge or tool is never used because it would cut the metal, though a tool tipped with a sharp piece of high-speed steel is used to trim the outside of a finished shell or to cut out any concentric holes needed.

The action is entirely one of stretching and drawing — no bending — exactly like deep drawing press work. Often spinning must be broken down into several steps. Thus, the 64-in. diam. cowl ring for the Grumman Wildcat fighter, made of 52S aluminum, requires breaking down and several anneals.

The chucks over which sheets are spun are practically always convex. Perhaps the most common chucks are made of Masonite wood, but the most accurate ones are of steel. Follow blocks are of wood or Masonite and run in live centers on the tail stocks of the lathe. The follow block provides the friction that makes the disc spin with the chuck and clamps the disc in position.

In one application a wood chuck was used for the roughing and an accurately-ground glass template used for the finishing. Typical peace work is parts of street lamps, searchlight reflectors and surgical reflectors.

—C. J. Holinger. *Mod. Machine Shop*, Vol. 18, Jan. 1946, pp. 124-128, 130, 132.

Making Large Gears

Condensed from "Western Machinery & Steel World"

Though gears have been used for 2,000 years or more they are still among the most difficult machine parts to manufacture properly. Surface wear is the most common cause of gear failure and may result from material defect, undue loading, shock, vibration, or improper tooth shape.

The good gear should be noiseless, wear-free and indestructible in normal operation, conditions which are realized only through competent metallurgy, precision tools in the hands of experts, optimum conditions of shop manufacture, and meticulous testing. Precisely formed teeth are the basic factor in gear silence.

The Joshua Hendy Iron Works, Sunnyvale, Calif., makes steel gears ranging from 3 to 147 in. diam., used chiefly as speed reducers for marine steam turbines and marine and stationary turbogenerator sets. The large fabricated steel marine gear consists of a separate rim and hub, two flanges or centerplates, and a number of radial webs to hold the flanges apart.

Positioners facilitate the welding of the big gears, used with Unionmelt machines, doing 25% of the welding and being more uniform and accurate than the hand job.

When rims of a 147-in. bull gear are of high carbon steel, the assembled blank is heated in a gas-heated pit furnace to 600 F

and removed for welding while hot and is covered with asbestos blankets to protect the welders and slow the cooling.

Gears after fabrication are treated in annealing ovens, 12 by 15 by 22 ft., equipped with flat cars running on tracks and heated by gas or oil. These big gears are of the nested type — two identical gears mounted with a space between them on the same shaft and mounted while hot, performing a shrink fit on the shaft, strengthened by fixed keys.

The entire assembly, weighing 27 tons, is removed to a 200-in., gap lathe for turning and facing to size, with tolerance limits of 0.001 in. Seventeen large hobbers in temperature controlled rooms can work to tolerances measured in ten-thousandths of an in. The plant also has modern gear shavers with capacities up to 96 in.

The finish cut is done on 160-in. double-head Gould and Eberhardt hobbing machines, cutting on both helices simultaneously. Provision is made for all work shocks.

All except the largest bull gears are finished on rotary gear shavers which produce a flawless finish and perfect tooth form. They remove thin, hairlike chips of 0.00025 in. or finer, automatically rectifying any small errors in index, helical angle, tooth profile, and eccentricity.

Dynamic balancing machines, with capacities of 0 to 25,000 lb., are also used, being able to indicate unbalances as small as 0.000025 oz.

—C. A. Sheffield. *Western Machinery & Steel World*, Vol. 36, Dec. 1945, pp. 547-551.

Flame Cleaning of Steel

Condensed from "Industrial Gas"

Too often when steel is cleaned with a gas flame preparatory to painting high-heating value gases are used in the work and the fuel cost is high. Then, if oxygen is employed, the cost is further raised. Moreover, these gases produce a very intense heat, there is danger of overheating and warping the steel, and considerable smoke is produced that hinders the workmen.

The Grandin Road viaduct in Cincinnati was flame-cleaned and the steel dehydrated preparatory to painting, using the 1000 B.t.u. city gas, with several advantages noted. The primary purpose of flame cleaning is to produce a surface that will provide a good bond for the paint. Either moisture or foreign matter will destroy this bond and cause premature failure of the paint.

The hot flame dehydrates the steel, loosens and burns all loose or heavy paint, dirt, rust, mill scale or scale in the form of blisters, scabs and all foreign matter. The flame travel is regulated to be fast enough for economy's sake, yet slow enough to do its job thoroughly.

After the flame process the steel is immediately wire-brushed to remove final traces of foreign matter. Then, while the steel is still warm, the paint is applied, doing a better job than were the steel cold. The paint is more viscous and more penetrating and spreads more evenly from the

spray gun. Flame cleaning was originally started in the shop but in recent years has been applied to outdoor steel structures.

The city gas on the Cincinnati job was applied with compressed air. There was 95,000 sq. ft. to be so processed. Light portable equipment was used. The low pressure gas lines and gas meter were protected from accidental air-back pressure by an oil seal. One air line and one gas pipe were suspended under the deck and run within 50 ft. of either end of the viaduct. Tees were spaced 40 ft. apart in these lines as connections for the air and gas hoses. Hose sizes were ½ in. for gas and ⅜ in. for air, with lengths in 50 to 100 ft.

Each torch uses 125 cu. ft. of gas per hr. Total gas consumption for the Cincinnati job was 85,000 cu. ft. Of course, there are not many locations where gas can be used for this outdoor work. The idea is more often to be applied to the shop fabricators.

—A. J. Pfetzing. *Industrial Gas*, Vol. 24, Dec. 1945, pp. 17-18.

Stainless Steel Scrap

Condensed from "Blast Furnace & Steel Plant"

Stainless-steel scrap could not be used by the early melters of stainless steel in the arc furnace, because of the problem of recovering the chromium from the scrap while maintaining a low-carbon content in the stainless-steel melt. Stainless-steel scrap became a drug on the market.

A little over 15 years ago, metallurgists and melters of stainless steels solved the technical problems of using stainless-steel scrap for melting stainless alloys. There resulted even more efficient recovery of the chromium in the scrap than had been anticipated and more accurate control of the carbon content of the steel. Stainless steel became a valuable commodity and an asset to the melter.

With the increase in number and complexity of stainless steels, new problems have arisen. To produce the many alloys, the melter of stainless steel must have properly segregated stainless-steel scrap. The scrap from the various stainless alloys cannot be intermixed or contaminated.

If the scrap generated from stainless steel is identified, accumulated, stored, sold, and prepared for remelting, according to the same American Iron & Steel Institute type number as the steel was originally bought, such scrap will be in constant demand by melters. Correct identity and proper separation are more important than the form.

In addition to keeping each A.I.S.I. type separate, contamination of the scrap by even small quantities of copper, brass, and other copper alloys, and tin or lead alloys must be avoided. The only practical method of determining if an individual lot of stainless-steel scrap has been properly separated and is free from contamination is chemical analysis of the scrap.

It is always preferable to ship only one grade of stainless-steel scrap in any one truck or car to avoid intermixing.

—L. F. Weitzenkorn. *Blast Furnace & Steel Plant*, Vol. 33, Dec. 1945, pp. 1511-1512, 1537-1538.

METHODS AND PROCESSES

TESTING and INSPECTION

Testing methods and equipment for physical and mechanical properties, surface behavior and special characteristics. Radiographic, spectrographic, identification, metallographic, dimensional and surface inspection. Stress analysis and balancing. Specifications, standards and quality control.

Structural Model Testing

Condensed from "S.A.E. Journal"

Design, construction and testing procedure used in connection with stress models developed by engineers at Goodyear Aircraft Corp. to check theories on stress analysis of the indeterminate rigid airship structure is discussed. Theoretical and model-test results agreed very closely.

The fundamental rule of similarity relative to stress models is that in order that a model can faithfully represent the prototype in both first- and second-order effects, it must be geometrically similar to the prototype both before and after loading. The principle of superposition is strictly correct only as long as the load-displacement relationship is linear.

Model girders may have any practical shape which gives them correctly scaled elastic properties. A number of models whose members accurately represent the elastic properties of the prototype have been built and tested.

The length scale should be chosen for convenience and economy because very accurate results are possible from either large or small models.

Metals are preferred for these models because they resist aging and humidity; temperature effects can be neutralized by using the same metal for the entire model; and, if properly chosen, will not be appreciably affected by creep under load. Hard-drawn or spring-tempered yellow brass and similar high-strength non-ferrous metals are used most because they have, in addition, good corrosion resistance, low modulus of elasticity, easy machinability, and good solderability.

Although plastics are excellent for some kinds of models because of their photoelastic properties, they are often seriously affected by aging, temperature, humidity, and a tendency to creep under load.

The manner in which a model should be assembled varies with the type. Assembly methods should receive careful consideration both before and during the design to achieve the proper degree of accuracy. These Goodyear models were generally assembled in carefully made wooden jigs. Model members should be calibrated before assembly to insure proper stiffness.

Testing methods are the indirect, in which stresses are obtained from influence lines, and the direct, in which scaled-down loads are applied directly to the models. Designs of models for both types of testing are fundamentally the same, in that they should correctly represent the stiffness of the prototype.

—O. W. Loudenslager. *S.A.E. Journal*, Vol. 54, Jan. 1946, pp. 18-25.

Device for Sorting Metals

Condensed from "Steel"

Tribo-electricity is electricity created by rubbing together two chemically dissimilar substances. Chemically identical substances subjected to frictional contact create no electrification. An instrument named the "Metalsorter" employs this effect as its basic principle of operation for sorting and identifying pure metals, steels, and non-ferrous alloys.

A standard reference specimen of known or acceptable character is reciprocated against the surface of the unknown piece and the potential developed is registered. The nature of the dissimilarity is indicated by the polarity and size of the potential developed, providing that there have been made preliminary tests involving the metals.

The testing tool consists of an assembly of a variable-speed motor-driven reciprocating mechanism, a bias control, a test-initiating push-button switch, a specimen-holding chuck, and a flexible connector lead with spring clip. All are mounted within a pistol-grip type aluminum housing, which is connected to the control unit by means of a multi-conductor cable equipped with a non-reversible plug.

The control unit houses a Thyratron timing circuit, an electronic bias supply circuit, a specially designed high-sensitivity microvoltmeter, overload protection devices, and adjustment controls. Only one "sensitivity" adjustment is mounted on the exterior panel. This is calibrated in one, two and four times the readings obtained at the minimum setting of 1.

The panel also contains an illuminated scale calibrated in mm., an On-Off switch, and receptacles for the power-input and testing-tool plugs. Control unit houses also the testing tool, cables, and fixtures. Operating power required is less than 100 w. at 115 v. and 60 cycles. Entire equipment weighs about 40 lb.

Testing procedure consists of having the instrument connected to a source of power and turned to "On", and chucking a reference standard into the nose of the testing tool and clipping the flexible lead to the piece to be tested. The standard is held in contact against a small cleaned area on the unknown, and any parasitic potentials are balanced to zero indications by the bias control. The test is then initiated.

Under average conditions, the time of reciprocation is held automatically to about ½ sec. at a frequency of 15⅜-in. strokes per sec. Pressure at point of contact is about 2 lb. If the specimens are dissimilar, the indicator on the illuminated scale will have moved to a maximum position.

To prevent seizure or scoring during reciprocation, a small quantity of lubricant is applied to the reference standard. Fixtures are provided for use of various sections and sizes.

Tests must be confined to comparing the chemical compositions of only those specimens which are known to be in approximately similar constitutional states. The surface should not be carburized or decarburized, and should not contain scale or rust.

—Antony Doschek. *Steel*, Vol. 117, Dec. 24, 1945, pp. 106, 109-110.

Salt Spray Testing

Condensed from "Monthly Review," American Electroplaters' Society

ASTM B 117-44T is an excellent and complete specification for salt spray testing, but more specific instructions are needed for reproducible results.

The 0.50 cal. Metallic Belt Link Committee of the U. S. Ordnance Dept. established seven essential requirements for salt spray testing: (1) Compressed air entering the box must have 84 to 90% relative humidity; (2) temperature inside the box must be 92 to 97 F; (3) atomization must be such as to give ½ to 3 cc. per hr. of fog; (4) collected fog must contain 18 to 22% salt; (5) pH of the salt solution in the reservoir must be 6.5 to 7.2; (6) specific gravity of the salt solution at 95 F must be 1.126 to 1.157; and (7) box and humidifier materials must be completely resistant to the salt solution.

In regard to the last point, Monel, hot tin dipped copper and rubber-lined mate-

rials have proved satisfactory for the saturator tank. Copper, or a combination of copper, rubber and Monel, may be used for the pipe line. Fixed Monel nozzles are recommended until something better is available. The suction pipe from the salt solution to the nozzle should be hard rubber. All equipment inside the box should be Monel or hard rubber.

It is recommended that the salt spray box be heated by a hot water jacket. An air pressure of 14 to 15 p.s.i. is best as higher or lower pressures increase the corrosion rate.

The salt solution should be made of 20 ± 2 parts by weight sodium chloride in 80 parts by weight distilled water. City water may also be used if the total solid content is under 200 p.p.m. The sodium chloride should contain under 0.1% sodium iodide and under 0.2% total impurities. The solution should be filtered before it is placed in the reservoir.

—H. P. Troendly, *Mo. Rev. Am. Electroplaters' Soc.*, Vol. 32, Nov. 1945, pp. 1110-1114.

Continuous X-Ray Inspection

Condensed from "Canadian Metals & Metallurgical Industries"

At the Elwood, Ill. ordnance plant operated by Sanderson and Porter non-destructive tests show flaws at any depth or thickness in the ammunition.

That portion of the X-ray beam that is reflected from the anode of the tube is used for radiography of shells and bombs carried around the machine on a continuous ring conveyor, while the beam transmitted through the anode is utilized for X-raying of still larger shells and bombs in the basement.

When no operations are under way in the basement, where the large shells and bombs were examined, a 10 to 12-in. lead shutter absorbs the transmitted beam. The transmitted beam is radiographically about five times faster than the reflected beam, although this disparity increases with density and/or thickness. This is based on the assumption that the distance of the film from the source of X-ray is the same in both cases.

On 8 in. of steel a 2,000,000-volt unit is 100 times faster than a 1,000,000 unit. What is lost on contrast and sensitivity is more than gained by the detection of defects in materials of widely varying densities and thicknesses.

The basic protection to personnel consists of an internal concrete wall and its lead shield, plus the 24-in.-thick concrete floor and walls.

Features of the X-ray machine include (1) the development of a large low-frequency resonance transformer which permitted insertion of the long X-ray tube in the center, and (2) the tube itself, actually a further development of the 12-section fernico-ring design used on the 1,000,000-volt apparatus. Permanently vacuum-sealed, the 2,000,000 volt tube contains 24 intermediate electrodes whose function it is to even the potential gradient across the tube.

—David Goodman. *Can. Metals & Met. Inds.*, Vol. 8, Nov. 1945, pp. 32-35, 52.

engineering BOOKS

Use of Fuel

THE EFFICIENT USE OF FUEL. *Published by Chemical Publishing Co., Brooklyn, N. Y., 1945. Cloth, 5½ x 8½ in., 807 pages. Price $8.50.*

This volume, prepared by a group of British technologists under the direction of the British Ministry of Fuel and Power, is a very complete and useful handbook, covering not only all phases of the subject of fuels but also the furnaces and other devices used for their combustion.

The purpose of the handbook is to improve the efficiency of fuel utilization, which has become a matter of immediate importance in Great Britain. All of their fuel, with the exception of imported petroleum, is either coal or is made from coal, a condition which might wisely be anticipated in America.

Their uses and problems are identical with our own, so that recommendations contained in this volume are of equal value to our industries, where there is yet some time to repair the barn door before the horse is stolen. For instance, the preservation of all coking coals for use by the metallurgical industries and the efficient use of coke oven gas (natural gas does not exist in Great Britain) are efforts which we could well afford to consider more seriously at this time.

In the discussion of the technical aspects of fuels and combustion, and of the laws of heat transfer, much practical data of value to engineers are discussed. Similarly, information on the flow of liquids and gases and their measurement is included to produce an unusually complete reference handbook on this subject.

Steam boilers and their auxiliaries are described, including an excellent chapter on waste heat boilers, which are seldom mentioned in American technical literature. The use of steam for all manner of purposes, including drying and central heating, and the equipment involved in its use, is covered thoroughly.

The discussion of industrial heating furnaces is taken largely from the books of our own Professor W. Trinks. All types of melting furnaces from cupolas to electric arc furnaces are considered, both in theory and in operation, and glass furnaces, cement kilns, and the many different types of calcining and drying kilns are described in detail. A large chapter is devoted to refractories and insulating materials.

Whereas the trend in this country is yet to convert practically all heat-treating furnaces (under 2000 F) to natural or artificial gas, the effort in Great Britain is to control producer gas, mechanical stokers, and powdered coal with sufficient accuracy to permit their use in these furnaces wherever possible. Such furnaces for annealing, hardening, carburizing and tempering are also equipped with recuperators, which practice is never considered in our furnaces in this category.

The use of mechanized heat-treating furnaces, developed in connection with the American automotive industry, has been extended by American furnace builders to the European continent, and the types described in this handbook may be recognized readily by American furnace engineers.

It is interesting to note that the necessity for accurate control of the heating of steel in its original ingot form is also recognized in Great Britain, and a suggestion that continuous car type tunnel kilns now being used may replace soaking pits will be of especial interest to American steel plants.

In conclusion, it is the opinion of this writer that the British Government is to be congratulated for its sponsorship of this inclusive and valuable handbook on the subject of fuels, which subject has already assumed great importance in many less fortunate parts of the world and will undoubtedly grow rapidly more important in the remaining sections where nature happened to provide more abundant amounts of available fuel.

—M. H. MAWHINNEY

Instrumentation

PRINCIPLES OF INDUSTRIAL PROCESS CONTROL. *By D. P. Eckman.* Published by John Wiley & Sons, New York, 1945. Cloth, 5½ by 8½, 237 pages. Price $3.50.

Control of temperature, pressure, rates of flow, etc. in manufacturing processes is accomplished first by measurement, finally, in many cases, by causing the measured changes to exert automatic, mechanical or electronic compensation for changes.

Instruments are the means of control. However, this book pays no attention to individual instruments; instead, it analyzes what needs to be accomplished and sets forth the principles that an adequate instrument must comply with. These principles are effectively illustrated by schematic line drawings.

The careful reader should be able to analyze his own problems, determine the applicable principles and then modify existing equipment, to become, or order suitable new equipment that is, adequate.

Whether as a text book in engineering courses or for study by plant men concerned with process control and instrumentation, this clearly written discussion of fundamentals will serve a good purpose.

—H. W. GILLETT

Other New Books

BIBLIOGRAPHY ON INDUSTRIAL RADIOLOGY, 1942-1945. *By Herbert R. Isenburger. Published by St. John X-Ray Service, Inc., Long Island City, N. Y., 1945. Heavy paper looseleaf folder, 9 x 11½ in., 13 pages. Price $1.00.* This pamphlet will undoubtedly be well received by many of those interested in or working in this field. It contains over 400 references culled from many American magazines and from some foreign publications. It is published as an addenda to "Industrial Radiology," second edition, 1943, John Wiley & Sons, New York.

Metal Cutting Shears with Pivoted Blade

The *Heavy Machinery Div., Cleveland Crane & Engr. Co.*, Wickliffe, Ohio, announces the introduction of a line of power-driven metal-cutting shears that employ a new pivoted-blade principle. Having no slides or guides, the upper blade operates on two heavy pivot pins secured to the end housing and travels in a circular path.

The new line, known as "Cleveland Steelweld Shears," may be readily arranged for squaring, slitting, or set at any intermediate position for notching, and firmly locked. This feature is included on all machines with standard 24-in. deep throats, but is not furnished on the smallest size, where the throat depth is 18 in.

A valuable feature is the ease with which the knife clearance can be varied to suit the thickness of plate being cut. Turning a hand crank located on the right end

housing changes the gap between the knives. A large dial indicator indicates the clearance in thousandths of an in., and also shows the plate thickness that may be cut for any knife setting.

Both frame and blade are of all-welded steel, one-piece construction. Because the knife adjustment is made by movement of the upper blade, there is no need of moving the bed, consequently, the beds on Steelweld shears are welded integral with the frames. Likewise, the large crown is welded to both end housings.

Other features include heavy spring-operated mechanical hold-downs which hold the plates firmly during shearing and automatically clamp thick plates with higher pressure than thin plates. An easy operating back gage mounted on ball bearings is provided. The shear angle or rake is low, thereby minimizing end thrust on the plate and reducing twist, camber and bow in the cut pieces.

Steelweld shears have been developed in various sizes for cutting plate of all thicknesses from 12 gage to 1¼ in. and for lengths from 6 ft. to 16 ft. Speeds range from 60 strokes per min. on the smaller shears to 25 strokes per min. on the largest size.

Noncorrosive Rust Remover

A new rust remover has been developed by *Nox-Rust Chemical Corp.*, Chicago. This new product is said to be particularly suited to problems of removing rust from precision bearings and machined surfaces without affecting critical dimensions.

Laboratory tests on highly polished roller bearings weighed to one ten-thousandth of a gram accuracy showed weight losses of less than 1/20 of 1% even after 8 hr. of immersion. Ordinary rust removal takes only a matter of seconds, however, leaving no perceptible etching or discoloration of surfaces.

This new rust remover can be applied by usual methods, such as brush, spray, and dip, but its long life and rapid action in otherwise inaccessible crevices make dipping the most economic wherever practical. Other uses include rust removal from castings, steel stock, fabricated parts, hand tools, periodically idle farm and process equipment, sporting goods from guns to golf clubs, and government surplus items exposed to weathering during storage.

Electrodes for Hard-Facing

One new and one improved shielded arc electrode, each of the type designed for specific hard-facing applications, is announced by the *Lincoln Electric Co.*, Cleveland.

"Abrasoweld AC," designated as a hard-facing shielded arc electrode, is designed for building up straight carbon steel, low alloy steel or high manganese steel with a self-hardening deposit to resist severe abrasion, battering and impact. Although specially designed for operation on alternating current, it may be used for both the industrial type and small, mass-market type welding machines and direct current.

Properties of weld metal of this new electrode are of the self-hardening type alloy which is semi-austenitic and abrasion resisting, and hardens very rapidly under conditions of impact and abrasion. Moderate peening will increase hardness as deposited from 20 to 40 Rockwell C to over Rockwell 50 C.

"Manganweld A," suspended for the duration, has been improved and is now

(Continued on page 848)


In Insulations, too
IT HAS TO BE RIGHT
THE FIRST TIME

AMONG MEN WHO KNOW HEAT TREATING BEST...

it's LEPEL induction heating 3 to 1

A Typical Installation of a Battery of Lepel Units at Eastern Heat Treating and Brazing Corp., 250 West 54th St., New York 19, N. Y. (Note absence of dirt and confusion in the photograph.)

Most Commercial Heat Treaters Have Lepel Induction Heating Units

If you want to try Lepel Induction Heating or want to secure its benefits but do not have sufficient volume of work to justify owning your own equipment, we'll gladly furnish the names of nearby Lepel-equipped commercial heat treaters who can do the work for you.

Commercial heat treaters — men whose business is heat treating — were quick to recognize and adopt high frequency induction heating as the fastest, most economical and most satisfactory method of heating for hardening.

They saw, in minimized distortion and decarburization, multiplied heating speed and possibilities for localized hardening, greater customer satisfaction and larger profits.

And, because they know heat treating, they have selected Lepel High Frequency Induction Units three to one over other makes for their plants.

They have learned from experience that —

Lepel Units are the most versatile. They can be used for any industrial heating job without any conversion except a simple change of load coils.

Lepel Units are most dependable. Their operating efficiency remains constant and the quality of work is uniform under all conditions.

Lepel Units are most economical. Relatively low in first cost, they operate at highest electrical efficiency at unity power factor.

Before you buy induction heating equipment — whether for heat treating, annealing, stress relieving, normalizing, soldering, brazing or melting (one Lepel Unit does them all) — compare Lepel Spark-Gap Operated Units point by point with all others.

Such comparison has made Lepel Induction Heating the 3 to 1 choice of men who know heat treating best.

See how Lepel Induction Heating will improve your heat treating or metal joining operations and cut costs. Send samples which Lepel Engineers will process to your specifications and return with complete engineering data and cost figures. No cost or obligation.

Lepel High Frequency INDUCTION HEATING UNITS

Just Off The Press — Send for your free copy of the new 32 page Lepel catalog — the latest, most authoritative work on induction heating.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
39 WEST 60th STREET NEW YORK 23, N. Y.

manufactured specially for reclaiming worn austenitic manganese steel parts containing 11 to 14% manganese. It is particularly well suited for use with direct current machines, and may be used with both the industrial type alternating current, and small, mass market type welding machine.

The weld deposit is air-toughening, remaining in austenitic state and retaining carbides in solution even during air cooling. The deposited metal has a resistance to abrasion and impact that is equal to heat-treated cast manganese steel. Weld metal, as deposited, has a hardness 5 to 10 Rockwell C and cold worked, a hardness of 45 to 50 Rockwell C.

● The development of two new X-ray tubes for industrial radiography is announced by *Machlett Laboratories, Inc.*, Springdale, Conn. One of the tubes eliminates undesirable extraneous radiation by means of an "electron trap" resulting in much clearer radiographs. Furthermore, the new design results in greater stability of operation and longer tube life. The other X-ray tube makes available radiation intensity of several million Roentgen units per min.

Tweezer Spot Welding Machine

For industries fabricating metal parts measuring 0.0005 in. to 1/8 in. round or thick the *Tweezer-Weld Corp.*, Newark, N. J., has developed a tweezer spot welding machine.

Heretofore the welding of tiny parts has been almost impossible because of the inherent difficulty in holding them in order to effect the weld. With the use of the tweezers, the electrodes may now be applied directly to the elements to be joined. The tweezers probe for the parts, hold and bend them, and weld.

Because the voltage used is low, and the current flows through the welding tweezers at about 1/1000 of a sec., the tweezers may

be held in the hands with absolute safety. They will not heat up even after continuous usage.

To weld parts from 0.015 in. through 1/8-in. round, the machine is used with an auxiliary booster unit which increases the capacity of the equipment by 300%. In

(Continued on page 852)


X-Ray Films
All sizes, all makes
Screens
Processing
Solutions
Lead Numbers
Penetrameters
Cassettes
RADIOGRAPHIC
industrial
x-ray
Accessories
VIEWING · FILING
DARK ROOM
Safelights
and Timers
Film Holders
Tanks
Filing
Cabinets
High Intensity
Illuminators
Dryers
Diffraction Film
Illuminators
Magnifying Illuminators
Fluorescent
Illuminators

order to weld some types of heavy gage metal where more pressure is required, the tweezers may be removed and the machine may be connected to a drill press or hand arbor.

Copper or copper alloy rods may be inserted as electrodes with only the bottom electrode insulated. The machine is then operated in the prescribed manner and more varied production is achieved.

● A new line of hand-forged deburring tools, which features seven distinct types, is available from *Metals Products Co.*, South Bend, Ind. The types, each in varying sizes, include a channel knife type, 45- and 90-degree angle hooks, as well as radius-curved ends, a straight scraping tool, and a "button hook" shaped deburrer. The complete line is made of fine tool steel, unimpeded operating shafts from 4¼ in. to 9 in. in length, hollow-ground, hardened, and specially tempered. These deburring tools are suitable for nonferrous, hard metal work, or plastics.

Automatic Pusher-Tray Furnace

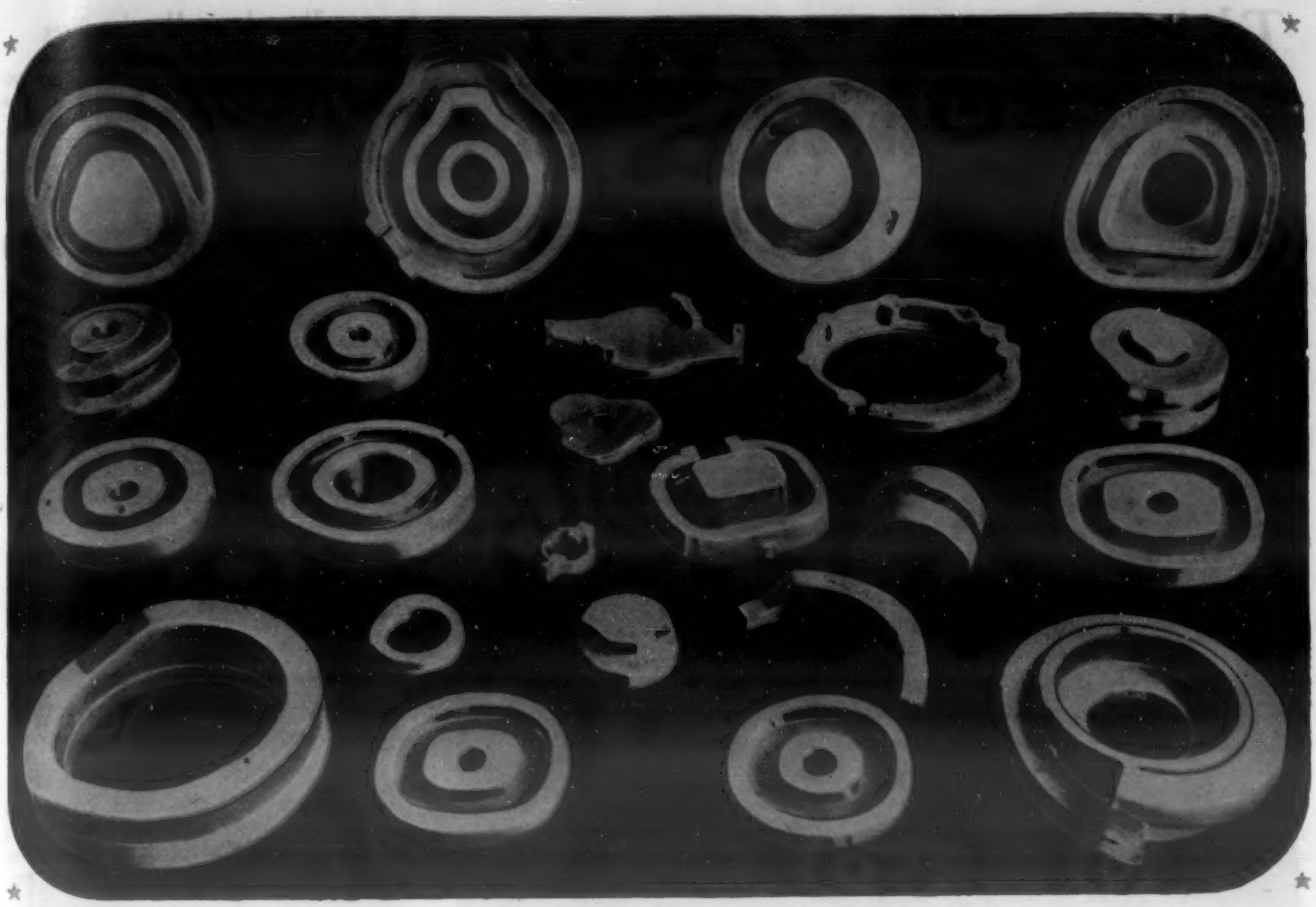
A new pusher-tray furnace has been built by *W. S. Rockwell Co.*, Fairfield, Conn., for heat treating large cast steel truck rear axle housings. This furnace was designed to heat the castings to 1650 F, hold them at that temperature for 1 hr. and then discharge them on an individual tray to enable them to cool uniformly in still air. Thus, every 12 min. one tray containing its load enters the heating zone of the furnace and one casting is discharged, the total normalizing time being 48 min. in the heating zone, and 60 min. in the holding zone.

The heating chamber of the furnace is approximately 15 ft. long by 6 ft. 5 in. wide. It is arranged with heating and holding zones, the higher zone being at charging end. A series of proportioning mixer type burners, utilizing natural gas, fires from both sides of the furnace above and below the work line, providing fine heat distribution and eliminating any areas of high heat density. The heat input for each zone is automatically controlled by separate recording potentiometer pyrometers.

An interesting feature of the operation is the manner in which the work cycle is progressed automatically. This is accomplished by a system that coordinates a time clock with the complete actuating mechanism to raise furnace doors, discharge heated work, push in new charge and lower doors in accordance with a predetermined operating program.

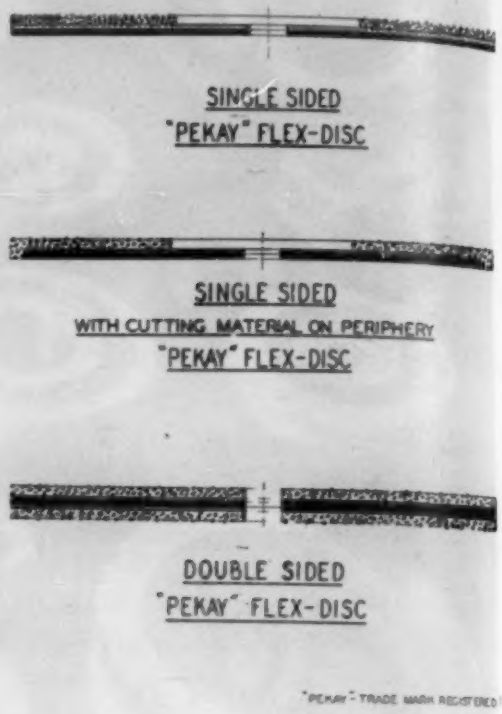
The castings for which this furnace was designed are 64 in. to 66 in. long, each weighing approximately 350 lb. The furnace is also used for normalizing on trays miscellaneous steel and alloy steel castings such as pump bodies, valve bodies, cylinders, agricultural machinery parts, etc., of all sizes and shapes in progressive movement through the furnace with the same controlled heating quality.

(More News on page 856)



Three Layer Abrasive Discs

A new type of abrasive disc for metal-finishing is announced by the *New York Grinding Wheel Corp.*, 623 Bergen St., Brooklyn, N. Y. Instead of the conventional form of a single layer of abrasive particles on cloth or paper, three layers



of materials—a bonded cutting layer, a cloth layer, and a fiber disc—are cured and bonded together to produce an abrasive disc with greater tensile strength, and augmented durability.

The discs are available with grits on both sides for grinding slots and grooves. Where sanding units are not portable but stationary, discs can be produced with a plain cloth back for cementing on stationary sanders.

These new type discs are also available with the leading edge elevated, so that a thicker layer of cutting material is supplied at the point of maximum wear.

New Arc Welding Electrodes

The *Metal & Thermit Corp.*, New York, announces a new line of heavy-coated aluminum bronze and phosphor bronze electrodes and two new groups of high tensile arc welding electrodes. Developed to meet the requirements of fabricators of power plant piping and equipment, but applicable to a variety of welding applications involving high tensile steels, the two new high tensile electrodes provide a wide range of well balanced mechanical properties and make it possible to select weld metal very closely matching many high strength steels in tensile strength and ductility. In addition, the all-position feature and the two types of coating provide versatility to meet a variety of working conditions.

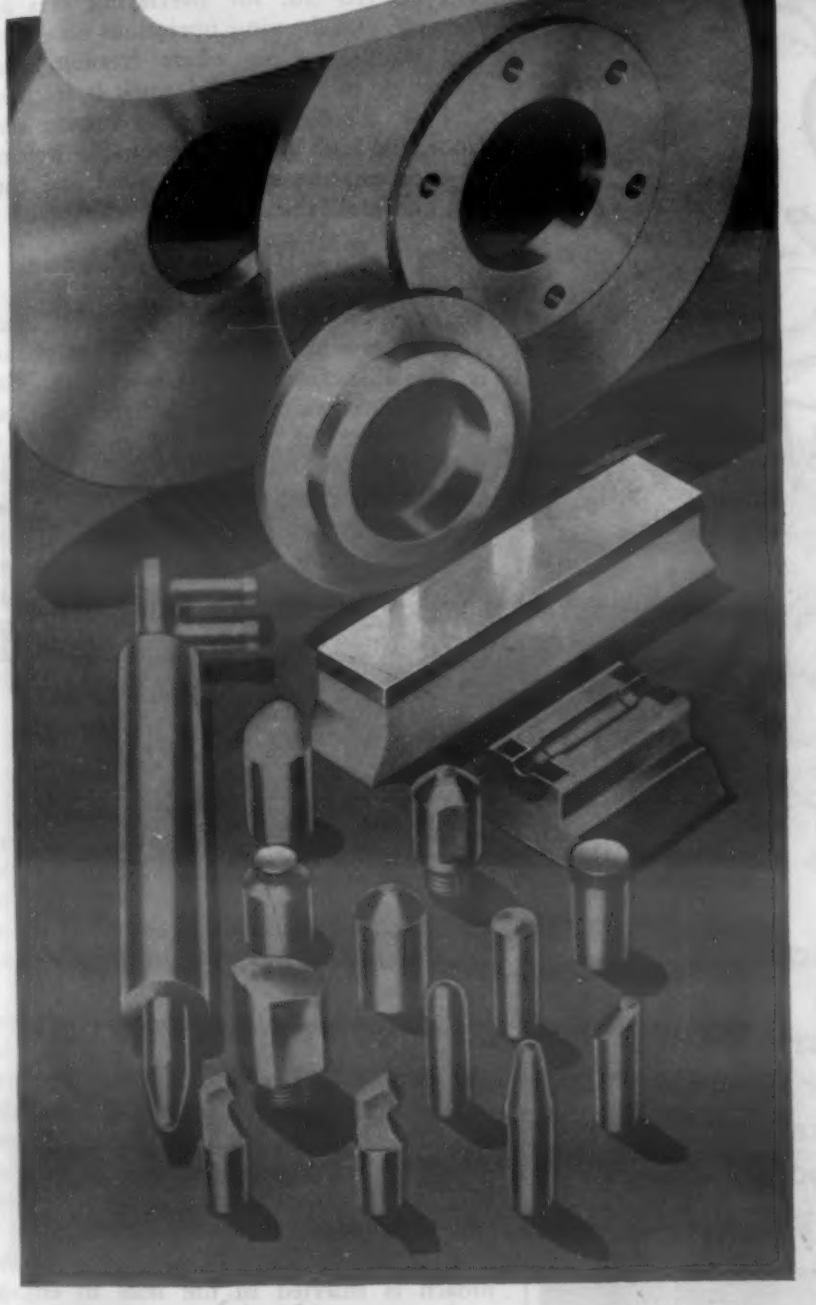
The new types of aluminum bronze and phosphor bronze electrodes including their uses are listed below:

Type AB 12, a general purpose electrode well suited to the arc welding of man-

(Continued on page 860)

P. R. MALLORY & CO. Inc.

MALLORY INSURES MELTS!



The addition of Lithium makes it easier for P. R. Mallory & Co., Inc. to meet its high conductivity requirements in these spot welding tips, seam welding wheels, and projection, flash and butt-welding dies. Mallory engineers also use Lithium for thin and complicated castings of Mallory 3, because it improves the fluidity and prevents mis-runs.

It is no accident that Mallory alloys are noted for their uniformly high electrical conductivity and high strength. To *insure* this uniformity, Mallory engineers specify the incorporation of Lithium in their proprietary copper base alloys.

This is sound insurance, because Lithium treated melts of copper, tin bronze and silicon bronze consistently yield castings more uniformly free from porosity and gas cavities, with nonmetallic impurities effectively removed, and with optimum physical properties . . . at a small fraction of the cost of *one* reject.

You might naturally expect a treatment so *effective* and *economical* to require a new and special technique. Actually, it is *simple*. Lithium treatment requires no special equipment, no special training, no departure from conventional foundry practice. Shortly before pouring, Lithium metal is stirred into the melt in the form of a stable master alloy containing a small percentage of Lithium combined with other metals to match the melt.

To help you investigate the advantages of Lithium treatment, we offer the services of our technical staff, with more than fifteen years' experience in finding the best practical answers to casting problems. Lithaloys Corporation, 444 Madison Avenue, New York 22, N. Y.

Recognized Authority on LITHIUM

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ganese bronze castings and brass sheets as well as to "arc brazing" of dissimilar metals such as steel to cast iron, cast iron to bronze or copper and steel, and iron, bronze or brass to nickel alloys.

Type AB 16, for repair or fabrication overlays on bearing surfaces subject to shock or impact.

Type AB 20, for repair, maintenance or fabrication overlays on machine parts subject to unusually severe service, such as building up worn heavy duty gears and repairing broken teeth. The deposit is also highly acid resistant.

Type AB 25, for overlay applications in building up bushings, bearings and slides operating against hardened steel which must stand up against heavy pressures and extreme wear.

Type AB 30, for overlaying dies for forming and drawing operations on carbon and stainless steels where freedom from scratching and galling of work is required.

Type PB 57, a phosphor bronze electrode, for high speed, high quality welding of bronzes, brasses, copper steel and both cast and malleable iron.

● A 24-in. disc grinder, adaptable to all kinds of grinding on metal, wood or plastics is available from the *Kindt-Collins Co.*, 12651 Elmwood Ave., Cleveland 11. Special features of the machine include a heavily ribbed, normalized and machined table; table tilt, 45 deg. down and 25 deg. up by worm and gear drive; both faces of grinding disc can be used; circular and core print fixture has a capacity of 22 in. in diam. and is wedge-shaped with 10 deg. angle. The disc will accommodate both flexible back cloth and paper back abrasives.

A Utility Broaching Machine

To fill the need for broaching equipment for large work which will eliminate the necessity of special work holding fixtures, the *Colonial Broach Co.*, Detroit 13, has developed a "Flat-top" utility pull-down broaching machine.

The machine, not intended for high production broaching, is designed with the platen horizontal, so that large, bulky parts can be slid onto the table and manually positioned without any other support. Thus, setting up for the broaching of one or several holes in a part, broaching of keyways, etc., becomes a simple matter.

To broach a part on this machine the broach is inserted in the hole to engage the broach puller. The broach is pulled down through the work by an hydraulic pull-mechanism. When the machine stops the part is moved aside and the machine then returns the broach to loading position, permitting its removal.

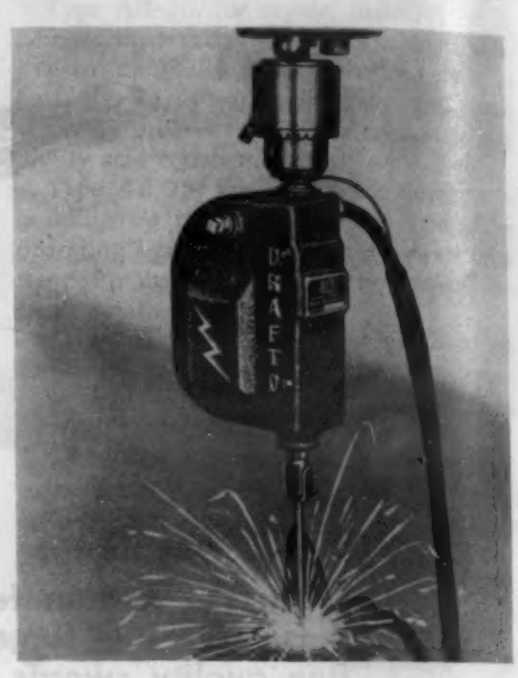
All operating mechanisms are concealed within the base. Provision is made for chip disposal through an opening in one side of the base. The machine is of 4-ton capacity with 30-in. stroke. It requires a floor area of only 42 by 65 in. The table measures all of 24 by 60 in., and its flat surface is just 48 in. above the floor.

(More News on page 864)

Broken Drill and Tap Remover

A new and improved type of metal disintegrator which rapidly and safely removes broken taps and drills from work in progress, thus saving the piece, is announced by the *Drafto Corp.*, Cochranton, Pa.

Known as the "Model 3 Drafto Metal Disintegrator," the new machine works on



the electrical "sputtering" principle and will remove broken drills or taps from work without injuring the metal of the workpiece. It is twice as fast as former models, and can bore through hardened high-speed steel at the rate of about 1/16th in. per min.

The new machine is not only a tap remover, but can be used as a drill. It will drill holes of practically any shape through hard metallic materials such as tungsten carbide and Stellite.

X-Ray Scanner

An X-ray scanner designed to overcome distortion and displacement that is present in all conventional methods of X-ray image recording has been introduced by *North American Philips Co., Inc.*, 100 E. 42nd St., New York. X-rays cannot be focussed (as with light) to give a parallel beam. Emitted by the tube's anode, the rays diverge to produce inaccuracies of greater or lesser degree, depending on the relationship of the particular film area to the X-ray source.

The scanner unit consists of a motor-driven table on which the specimen and film move beneath an adjustable slit through which the X-rays pass. The scanner precisely records the geometric relationship of integrated components and spacings of segmented specimens.

The scanner is especially useful in the manufacture of vacuum tubes, capacitors, switches, breakers, timing devices, storage batteries, or any precision assembly where space measurements are desirable after parts are integrated.

When fine grain X-ray film is used, enlargements may be made for more accurate determination of element position and condition. This can serve to check component

(Continued on page 868)

changes after certain periods of service. The scanner may also be applied to determine accurately the unknown thickness of material and to study intergranular structure of metals and plastics.

● A treatment to produce from plasters such as plaster of Paris a new product which is harder than marble and as strong as stone has been developed by *Engineering Associates,* St. Charles, Ill. The new material, known as "Palestic," is being considered for a number of industrial products, including drawing forms, patterns, instrument bases and containers. The process for making "Palestic" involves no special equipment. It is ten times more resistant than plaster to penetration by water, and can be sanded, sawn, polished and generally handled like a plastic.

Die Casting Machines for Heavy Castings

Two new die casting machines for the production of large, heavy castings are now offered by *Lester-Phoenix, Inc.,* of Cleveland. One of the machines is designed for zinc, tin and lead alloys, and the other for aluminum, brass and magnesium.

Common to both machines is the machine frame, which is a one-piece steel casting that achieves a high degree of rigidity. Weaving, wear and stress, which occur at the joints of a fitted frame, or at the juncture of tie bars and die plates in a bar-type frame, are completely eliminated. The locking pressure possible within this frame is rated at 600 tons.

The central die support in both machines has been increased in size, and the movable die plate has bearing on all four corners, eliminating possibility of deflection as the die is closed. Die height is accomplished by means of a single hand crank through worm and worm wheel rotation of the large adjusting screw.

The aluminum machine is equipped with a patented pre-fill injection system, which injects metal rapidly at controlled speed and then applies the greatest pressure to the metal as it chills in the die, squeezing out shrinkage voids and trapped air and gases to eliminate porosity in the finished castings.

This equipment develops injection pressure of 33,000 psi., applied to castings up to 40 in. in projected area. Higher pressures per sq. in. naturally can be applied to smaller castings. Aluminum castings up to 14 lb. each can be made on this machine.

The hot metal injection system of the zinc machine has a one-piece cylinder and gooseneck of heat and corrosion resistant alloy semi-steel casting, with a high-speed cylinder liner and plunger. Furnace and pot are round, with tangential flames for faster, more uniform heating. Injection pressure is held upon the metal as it chills in the die. Zinc castings up to 19 lb. each can be made on this machine.

(More News on page 872)

Photographic Reproduction Process

A new process by which metal, wood, cloth, leather, plastics or almost any other surface can be made usable for photographic reproduction has been developed by the *Glenn L. Martin Co.*, Baltimore.

Basis of the new process is an emulsion which can be spread on many kinds of

materials, sensitizing them for photographic print use. In its normal state the emulsion is a thin jelly-like substance which, when heated to a temperature of 125 degrees, becomes a liquid which may be applied to the desired surface with a camel's hair brush, a soft sponge or a soft rag. Allowed to dry, the negative is then printed on the sensitized surface and development proceeds normally as if it were a commercial paper.

All operations are carried out under darkroom conditions, using ruby lights. The emulsion may be heated any number of times without effecting its efficiency or printing qualities.

In industry the process will have its uses in the reproduction of drawings for manufactured products or machinery. Such drawings can be either to full scale for ease in reading and checking during manufacturing process, or can be reduced if prints to carry are desired. Proportions remain, of course, exact and the need for redrawing to a different size, with possibility of error, is eliminated.

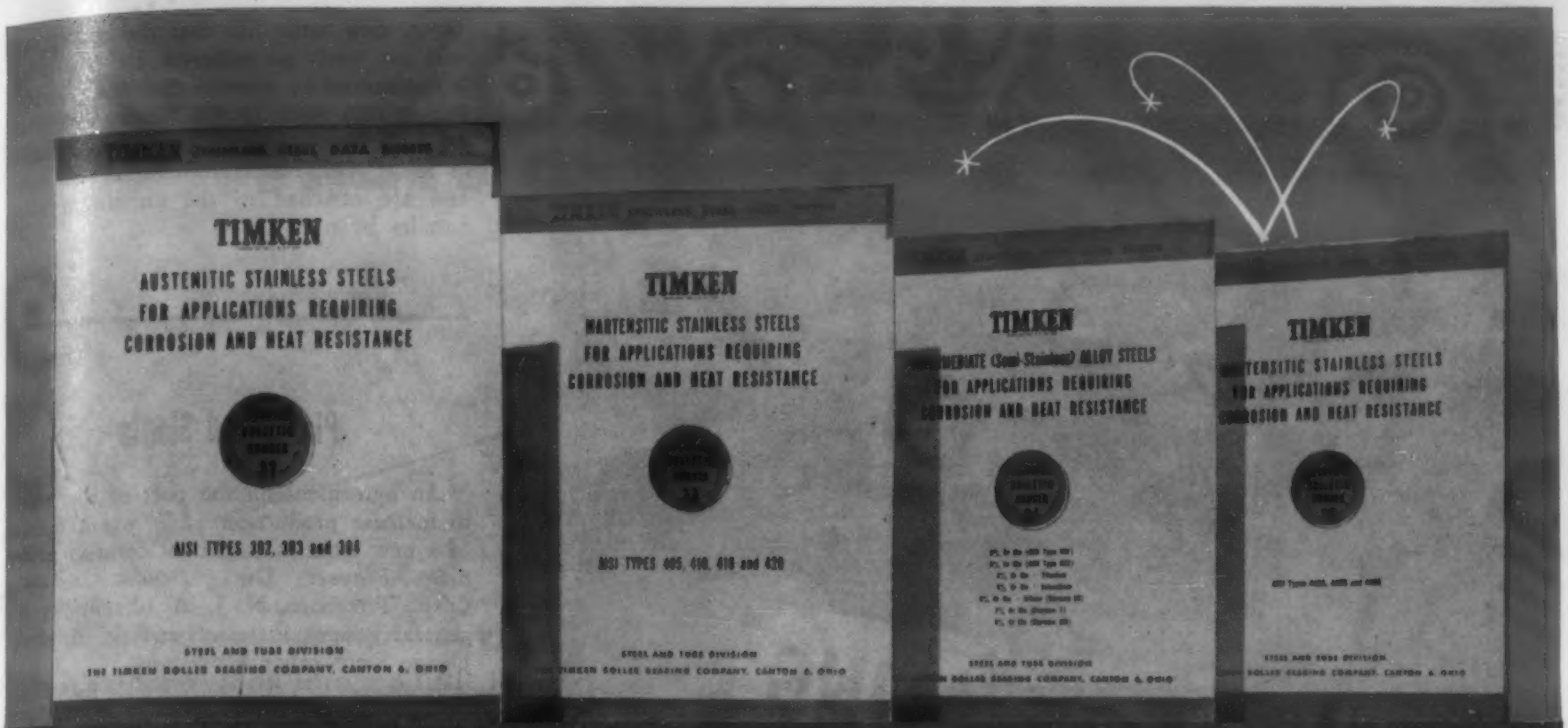
Electric Furnace for Hardening High-Speed Tool Steels

A new high-speed steel hardening electric furnace to be added to their line of Model "Y" furnaces is announced by the *Sentry Co.*, Foxboro, Mass. The new model, to be known as "Size #5," has a muffle chamber 7 in. high, 8⅞ in. wide and 20 in. deep, and will handle high-speed steel tools up to 5 in. by 7 in. by 14 in.

Several design innovations are incorporated in this new furnace. Heating elements are located front to rear alongside the removable muffle chamber. Heating element terminals are the same air-cooled type as used on other Model "Y" furnaces.

The furnace heating chamber is designed to reflect heat toward the muffle chamber opening to offset the tendency to cool at this point. Terminals and electrical connections are shielded and protected by removable metal guards.

(More News on page 876)



Are You Up-to-date on STAINLESS STEELS?

Do you know how more and more manufacturers are using Timken Stainless Steels for product improvement?

Do you know about the simple new techniques for machining, forging and heat-treating these steels to your own requirements in your own plant?

Are you familiar with the outstanding properties of the new stainless steels developed by The Timken Roller Bearing Company; 16-25-6 which made possible the American jet propulsion engine? And 16-13-3? And many others?

If you must answer "no" to any of these questions, you should have our new series of Stainless Steel Data Books. They contain many facts which will be helpful to you—all based upon our long years of experience as a major *producer* of the finest stainless bars and tubes. Their viewpoint therefore is extremely practical.

We will gladly send these booklets without cost to interested manufacturers who request them on their own letterhead. Ask for Stainless Steel Data Booklets No. 32, 33, 34 and 35. Address Steel and Tube Division, The Timken Roller Bearing Company, Canton 6, Ohio.

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SPECIALISTS in hot rolled and cold finished Alloy Steel Bars for forging and machining applications, as well as a complete range of Stainless, Graphitic, and Standard Tool Steel analyses. Also Alloy and Stainless Steel Seamless Tubing for mechanical and pressure tube applications.

● A new lathe file that the maker says will cut steels no ordinary file will touch is announced by *Kennametal, Inc.*, Latrobe, Pa. It cuts three to ten times faster than ordinary files, with a life 50 to 200 times as long. The blanks have brazed-on nuts, and are attached to the aluminum alloy handles by screws.

Plants and Slants

An agreement on the part of the union to increase production 15% was a feature of a new labor-management contract at the *Eclipse-Pioneer Div., Bendix Aviation Corp.*, Teterboro, N. J. A 12-cent per hr. general wage increase and a no-strike pledge were other provisions.

The *Reynolds Metals Co.* will on April 1 give pay increases to all salaried employees earning \$5,000 a year or less on an equal basis with those recently given production workers as of that date. As the management expresses it, "We don't want the salaried people to be just another 'forgotten man'."

Milling and processing facilities of the *Foote Mineral Co.* are being centralized in 30 acres at the Exton, Pa. plant where a new mill building and large new warehouse are being erected. Ores and minerals from all over the world will be processed at this plant. Offices have been moved to the entire fifth floor of the Germantown Trust Co. Bldg., 10 E. Chelten Ave., Philadelphia 44.

The *International Nickel Co., Inc.*, has opened the Twin Cities technical section of its Development and Research Div. in the Northwestern Bank Bldg., 620 Marquette Ave., Minneapolis. It is in charge of J. C. Neemes, Jr., metallurgist.

The *Dampney Co. of America*, Hyde Park, Boston 36, has acquired the Thurmalox Co., Doylestown, Pa., maker of black and aluminum preparations for coating hot dry surfaces up to 1600 and 1200 F, respectively—and other coatings.

A group of experienced steel men has bought the Crum Lynn Foundry, Chester, Pa., built by the R.F.C. The new company, the *Chester Electric Steel Co.*, will specialize in carbon alloy and stainless steel castings. It is headed by Fred Grotts, president of Fort Pitt Steel Casting Co. since 1939.

The name of the *Abrasive Co.* of Philadelphia has been changed to Simonds Abrasive Co. The original company was founded in 1892 and has made grinding wheels, etc. In 1927 it was bought by Simonds Saw & Steel Co.

The *Precision Welder & Machine Co.* has purchased a building at 138 E. McMicken Ave., Cincinnati 10, containing 25,000 sq. ft. of space.

American Steel & Wire Co. will spend \$1,000,000 to modernize and increase pro-

(Continued on page 880)

What's all this about SUPERFINISH?

If you've thought of *Superfinish* as a lavishment, then perhaps it's time to look into it a little further. You'll find enough evidence to change your notions—and perhaps give you a new competitive advantage in the form of lower costs.

No matter how fine a ground surface may appear to the eye, it has defects . . . scratches and ridges produced by the point of the turning tool . . . larger defects such as grinder feed spirals and chatter marks . . . partially loosened splinters of metal ready to come off on contact with another surface . . . soft surface metal, annealed by the heat of the grinding wheel. In practically every case, fragmented metal will be torn from the mating surfaces to mix with lubricants, causing abrasive wear and creating a larger amount of clearance.

Superfinishing prevents this by removing both grit scratches and longer pitch defects due to minute machine tool inaccuracies. It provides the surface smoothness to maintain a uniform oil film—to reduce wear—to eliminate bearing trouble and lengthen bearing life.

Superfinishing is a quick and inexpensive process. And in many cases it can reduce present manufacturing costs by eliminating other more costly processes. This is a good time to get complete information about *Superfinishing*. Write us.

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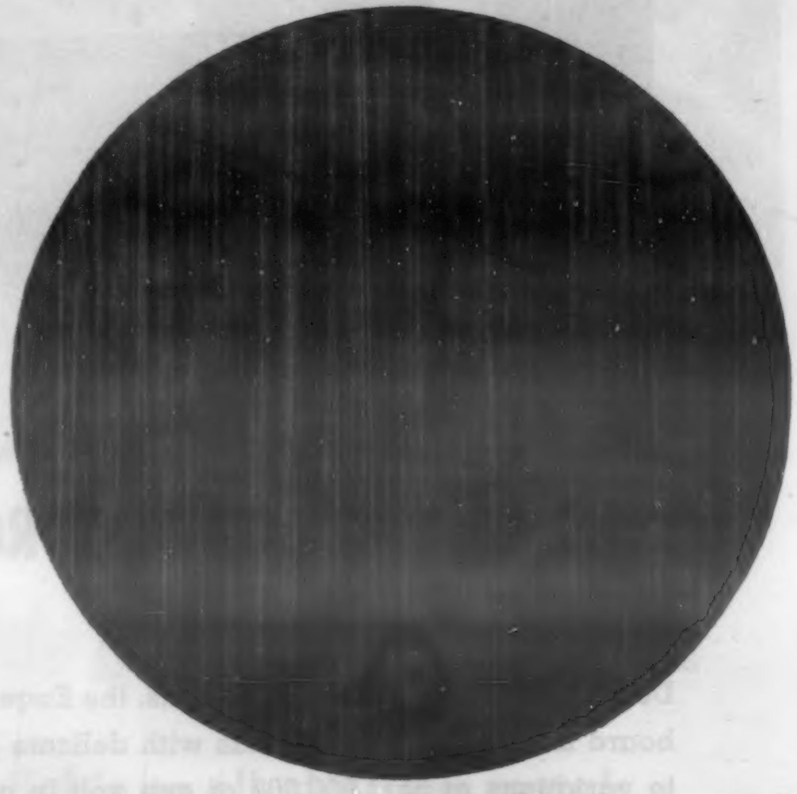
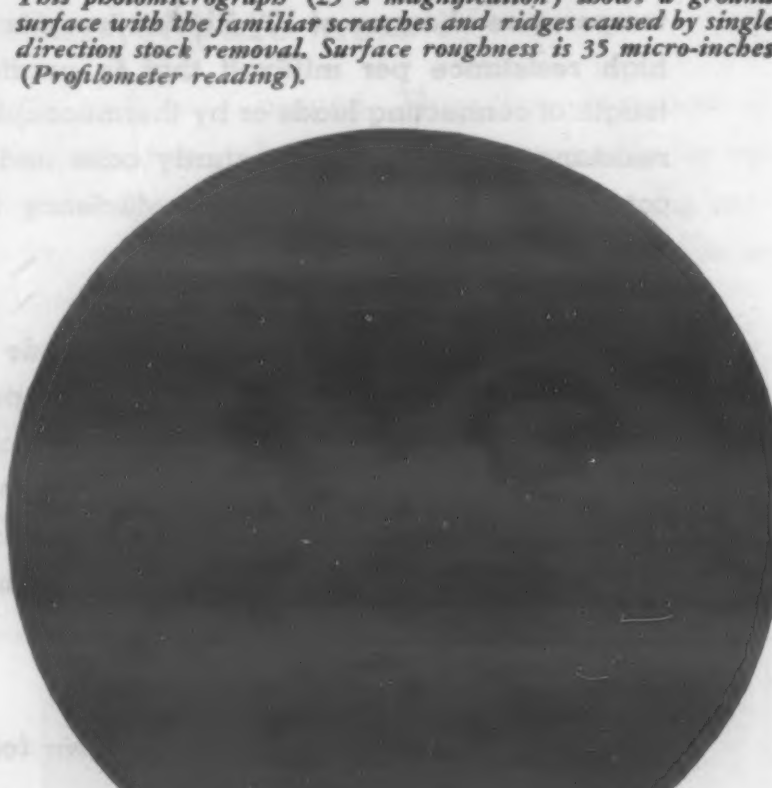


This photomicrograph (25 x magnification) shows a ground surface with the familiar scratches and ridges caused by single direction stock removal. Surface roughness is 35 micro-inches (Profilometer reading).



The same piece, 30% Superfinished *to 15 micro-inches. Note how ridges have been reduced. A completely* Superfinished *surface of 2 to 3 micro-inches will leave no defects to penetrate the oil film or abrade the mating surfaces.*

TURRET LATHES • AUTOMATIC LATHES • SUPERFINISHERS • BALANCERS • SPECIAL MACHINES

duction of stainless steel wire at the Waukegan, Ill., works. The project includes facilities for a completely integrated unit, drawing and processing, from hot rolled rod to the finished product.

The *Tinius Olsen Testing Machine Co.*, Philadelphia, celebrated its 100th anniversary on Dec. 7, 1945.

Federated Metals Div., American Smelting & Refining Co., has opened a new $100,000 physical testing laboratory at the company's Whiting, Ind., plant under the supervision of Don Graves.

A new mechanical research laboratory for *Air Reduction Sales Co.* and subsidiary companies is being constructed at New Providence (near Summit), N. J., for development of processes and apparatus for using industrial gases and the electric arc, particularly in the cutting, welding and treating of metals. The buildings are of the latest ultra-modern functional design.

A new engineering organization, the *Central States Engineering Corp.*, has been formed at 4612 Woodward Ave., Detroit 1. It will help manufacturers with the designing of tools, jigs, dies, fixtures, gages and special machinery. E. M. Beyma is president and general manager.

The *Barium Steel Corp.*, Canton, Ohio, has acquired control of Globe Forge, Inc., Syracuse, N. Y., steel forging and manufacturing concern, which furnishes drop and upset forgings to several industries.

I. Schumann & Co., Cleveland, smelters and refiners, have purchased a large tract of land with rail and water haul at Cleveland and will construct a new $200,000 plant.

The *Glenn L. Martin Co.* will build a $1,500,000 plant at Baltimore for the manufacture of its new elastic plastic, Marvinol resin.

The *Davis Boring Tool Div.*, Larkin Packer Co., Inc., St. Louis, has been acquired by the *Giddings & Lewis Machine Tool Co.*, Fond du Lac, Wis.

New general headquarters of the *Gehnrich Oven Div., W. S. Rockwell Co.*, have been established at 200 Eliot St., Fairfield, Conn., having been moved from Brooklyn, N. Y.

American Brake Shoe Co. has bought *Joliette Steel, Ltd.*, one of the largest producers of manganese and alloy steel castings in Canada.

Briefs on Associations, Promotions and Education

The annual meeting of the American Society for Testing Materials will be held at the Hotel Statler, Buffalo, June 24-28. There will be 15 to 20 technical sessions, many meetings of technical committees, an exhibit of testing apparatus and related

(Continued on page 884)

equipment, and the annual photographic exhibit. The Society of Experimental Stress Analysis joins A.S.T.M. in a symposium on testing parts and assemblies.

At the annual meeting of the Forging Manufacturers' Assn. in New York in January, R. B. Heppenstall, president, Heppenstall Co., Pittsburgh, was elected president. W. J. Parker is secretary, and headquarters are at 366 Madison Ave., New York 17.

Louis W. Kempf, assistant director of research, Aluminum Co. of America, has been elected chairman of the Institute of Metals Div., American Institute of Mining & Metallurgical Engineers. The Institute, the oldest and largest scientific body in the field of nonferrous metals, has 16,000 members. Mr. Kempf is inventor of many aluminum alloys and is author of numerous articles on aluminum metallurgy.

The Steel Founders' Society of America, 920 Midland Bldg., Cleveland 15, has elected E. D. Flinterman of Michigan Steel Casting Co., Detroit, as president. Raymond L. Collier continues as executive secretary.

The American Gas Assn. conference on industrial and commercial gas has changed its meeting date to March 29 and 30 at the Commodore Perry Hotel, Toledo, Ohio. Among its topics will be prepared atmospheres and high-speed direct heating.

A school of precision casting has been established at 136 W. 52nd St., New York 19, by J. F. Jelenko & Co., Inc. The school is licensed by the State of New York and is approved for veterans under the G. I. Bill of Rights. The course is primarily a practical shop and laboratory one. The complete course requires 168 hr., with day or night sessions.

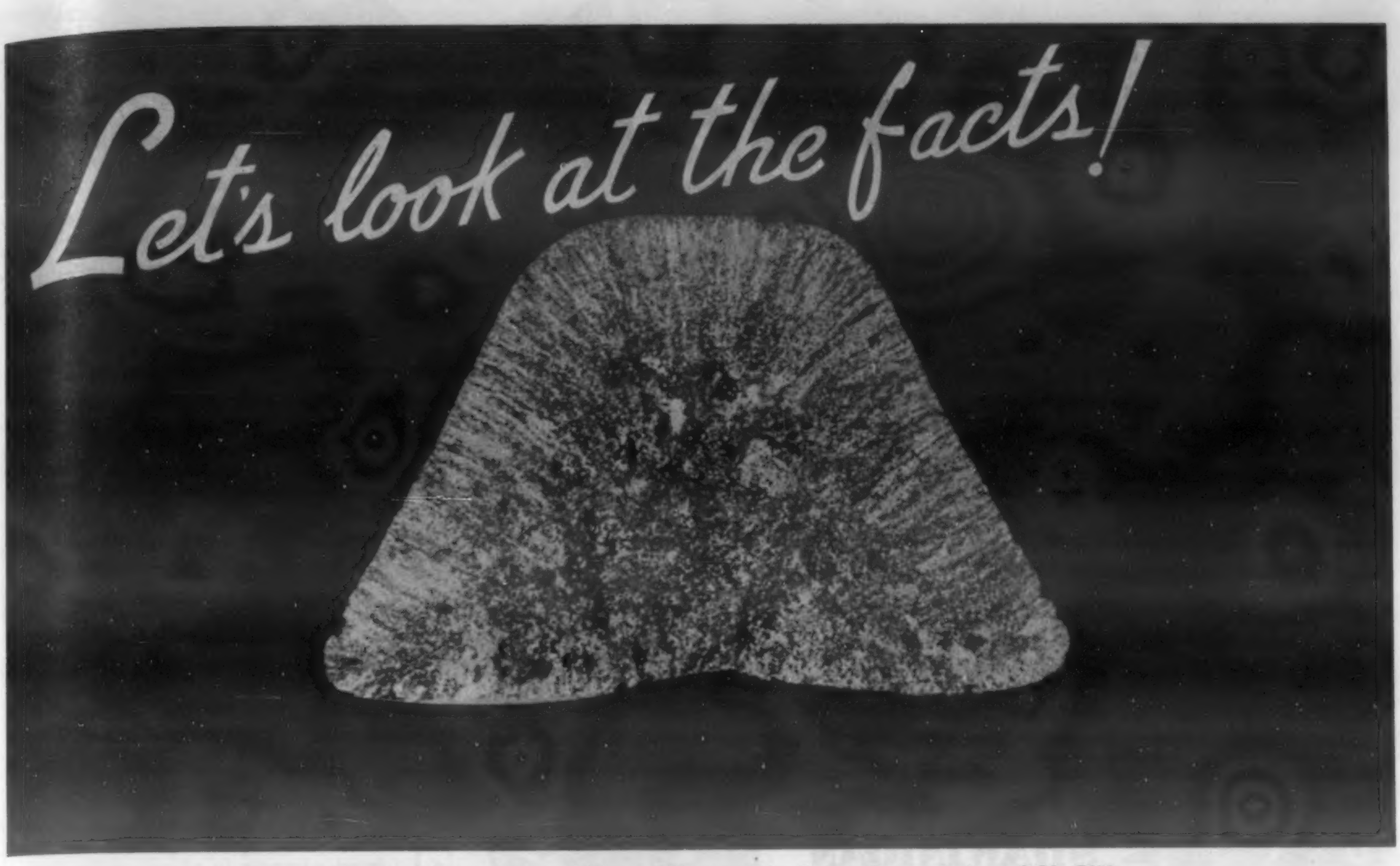
If men and money are working there is neither time nor need for economic meddling. That is the gist of a standard 35-mm. sound-slide film, "Free American Way," put out by Mullins Mfg. Corp., Salem, Ohio, to show how American industry can meet the challenge of changing times. It is available to any group.

Four metallurgists have been appointed assistant professors at the new Institute for the Study of Metals at the University of Chicago. They are: Joseph E. Burke, Los Alamos atomic bomb laboratory; Andrew W. Lawson, University of Pennsylvania; Norman Nachtrieb, Los Alamos project; and Adam Skapski, Polish metallurgist.

The Resistance Welder Mfgrs. Assn., Citizens Bldg., Cleveland 14, offers awards of $2000 in 1946 for outstanding papers dealing with resistance welding. Five judges will be appointed by the American Welding Society. Minimum length requirement for papers is 2500 words. The contest closes July 31, 1946.

A conference, the first of its kind in the Chicago district, was that scheduled for the La Salle hotel, Chicago, March 5 and 6, called the Midwest Quality Control Conference. W. E. Jones, conference chairman, calls statistical quality control "the newest

(Continued on page 888)


Let's look at the facts!

of management's industrial tools for adequate plant control." The publicity chairman is Lt. J. L. Shafer, 901 Argyle St., Chicago.

The only film on the wet belt machining method of surfacing, grinding and stock removal is now available from the Porter-Cable Machine Co., 1714 N. Salina St., Syracuse, N. Y. The film is a 16-mm. sound, black and white visual presentation, called "A Machine of the Age."

First Grand Plastics Exhibition

The first exhibition of the plastics industry on a national basis will be held in Grand Central Palace, New York, April 22 to 27 under the auspices of the Society of the Plastics Industry, 295 Madison Ave., New York 17. Some 200 companies, the industry's leading manufacturers of raw materials and machinery, will participate, and attendance will be drawn from all parts of the United States and Canada, Latin America and Europe.

Concurrently with the exposition the Society will hold a convention at which leading authorities will tell latest advances in plastics technology and application. A special housing bureau will facilitate securing of accommodations for visitors.

The general public will be admitted to the exposition only during the last three days of the showing. Presented will be the basic plastic materials, the machinery that fashions them, methods and services for doing it—and the ultimate products themselves.

News of Engineers

Dr. Raymond G. Spencer, chairman, Metals & Minerals Research Div., Armour Research Foundation, Chicago, has become director of the Washington University Foundation, St. Louis. He will assist industries in research and development. He is a member of several technical societies.

Fred P. Peters, editor-in-chief of MATERIALS & METHODS, has also been appointed Associate Publishing Director of Reinhold Publishing Corporation's Book Division. In this capacity he will assist in expanding the company's book-publishing activities, especially in the metallurgical, metalworking and materials engineering fields.

Dr. D. S. Eppelsheimer has been appointed sales manager and chief physical metallurgist of Metal Hydrides, Inc., Beverly, Mass. He was formerly in charge of a research project at the University of New Hampshire.

Kenneth M. Downes, formerly supervisor of process inspection at Remington Arms Co., Bridgeport, Conn., is now materials engineer, Office of the Chief of Ordnance,

(Continued on page 892)

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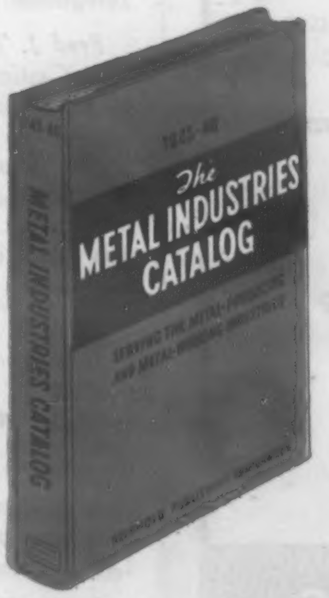

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War Department, Washington, D. C., specializing in specifications for ferrous and nonferrous metals and alloys.

Clifford E. Horner has joined J. F. Jelenko & Co., New York, as metallurgist and head of the research department, the company making dental gold alloys used for casting and soldering. He has been with the R. C. A.-Victor Div. at Harrison, N. J. for nine years as a metallurgist in radio tube manufacturing.

Sterling T. Boyd has been made plant metallurgist, Colonial Steel Div., Vanadium-Alloys Steel Co., Monaca, Pa., previously having been chief inspector.

Joseph Mazia, formerly head of the Protective Finishes Section, Ordnance Research Laboratory, Frankford Arsenal, has become metallurgist in the Metal Surface Treatment Div., American Chemical Paint Co., Ambler, Pa.

Thomas M. La Crone, for ten years a metallurgical specialist with General Motors, has been made supervisor of research and the experimental laboratory of the Lithium Co., Newark 4, N. J., maker of atmosphere furnaces.

Dr. Arthur H. Grobe, formerly with the metals research laboratory, Carnegie Institute of Technology, is now chief research metallurgist, Vanadium-Alloys Steel Co., Latrobe, Pa.

G. D. Moomaw has been made general manager of the Rustless Iron & Steel Div., American Rolling Mill Co. Prior to joining Rustless in 1939 he was with the Crucible Steel Co.

Gustaf A. Ostrom has become chief research engineer with Alloy Rods Co., York, Pa. Previous experience has been with Foote Mineral Co. and Arcos Corp.

Lt.-Col. Charles H. Greenall, director of research at Frankford Arsenal, becomes executive director of the Franklin Institute Laboratories, Philadelphia, on April 1. He is a mechanical engineer, specializing in materials development and was once in charge of metallic materials at the Bell Telephone Laboratories.

Fred J. Tobias has joined Advance Pressure Castings, Inc., Brooklyn 22, N. Y., to take charge of production and metallurgy. He has written several papers and books, largely on die castings, has lectured extensively before technical societies, and belongs to several technical societies. He was born in Czechoslovakia and educated in Austria, Moravia and at Yale University.

John M. Guthrie has become technical director of the Fidelity Chemical Products Corp., Newark 4, N. J., maker of cleaning compounds, stripping compounds and detergents. For the past twelve years he has done research and development for Aluminum Co. of America and Bell Telephone Laboratories.

J. W. Wheeler, formerly manager, Rolls-Royce permanent mold foundries in England and advisor to the Reynolds Metals Co.'s casting division, has opened offices in the Worthington Bldg., Springfield, Mass., as a permanent mold consultant.

(Continued on page 896)

Myron B. Diggin, chief chemist, Hanson-Van Winkle-Munning Co., Matawan, N. J., has been appointed director of a project to investigate the effect of polishing nonferrous metals on the protective value of electroplated coatings on them.

E. B. Pool, for ten years a mechanical and experimental engineer with Chrysler Corp., will conduct a new type of valve research work for Edward Valves, Inc., E. Chicago, Ind. He will specialize in stress and strain experiments. During the war he headed the physical testing laboratories and material and process standards at the Dodge-Chicago plant.

House Organ Notes

Grits and Grinds, Norton Co., Vol. 36, No. 11

Death Valley, a desolate sandy plain in California, close to the border of Nevada, is 150 miles long and 35 miles wide. The plain is 210 ft. below sea level and is destitute of vegetation except for cacti and greasewood. Summer heat rises to 130 F, and on the adjoining mountains in winter 30 below is reached. The only animal life is an occasional crow, buzzard, horned toad, jackrabbit and rattlesnake. Here prospectors first found the basic mineral for making the hardest material ever produced by man —"Norbide," or Norton boron carbide. The very purest quality of boric acid is now taken from Searles Lake near the edge of Death Valley, a lake so loaded with crystalline solids that it has a crust as strong as a layer of ice. Water is removed from the boric acid crystal which changes it to a hard glass. This is only the beginning of an interesting process.

Midvale Safety Bulletin, Midvale Co., December, 1945

Midvale's new 2,000,000-volt X-ray will radiograph defects in a lightly alloyed jet propulsion rotor forging 7⅜-in. thick in only 1 min. When Roentgen, discoverer of the X-ray, tried to make an X-ray picture of his wife's hand in 1895, he used a tube energized by 20,000 volts and it required 30 min. exposure to affect the photographic plate. The radiation from Midvale's new machine is 15 times as intense as that of present day X-ray tubes used in destruction of cancer. It is equal in radiative power to $200,000,000 worth of radium, about 6 times the entire available supply in the world.

Toledo System, Toledo Scale Co., January, 1946

The U. S. has no standard pound or foot. Our measurements of weights and length are based on the standard kilogram and the standard meter of the metric system. These standards, made of platinum and iridium, are kept buried by the U. S. Bureau of Standards in a thermostatically controlled sealed vault. The foot and pound are mathematically calculated from the metric

(Continued on page 900)

NOT MERELY BECAUSE IT *improves* THE PRODUCT...

BUT BECAUSE IT

stimulates product acceptance

—nothing equals Stainless Steel!

It is for good reasons that equipment manufacturers — whether they make chemical apparatus, food plant equipment, textile machinery, trains, planes or household appliances — always *emphasize* the fact when their product is built with Stainless Steel.

They use Stainless because it does a better job. And they tell the public so, because to the industrial purchaser, as well as to the man on the street, "Made of Stainless Steel," like the sterling mark on silver has come to signify tops in quality.

Stainless Steel means practical immunity to corrosion, stain or tarnish. It means easy cleaning. It means high resistance to heat, to wear and abrasion—superior strength and toughness that assures long life under hard usage. It stands for eye-catching beauty that will not fade, inherent goodness that will not wear off.

Everyone knows that despite wartime shortages, Stainless Steel was assigned ever increasing numbers of the tough jobs of the war. Why? Simply because Stainless would stand up much longer than the materials it displaced. Here is another good reason why Stainless Steel is today so generally accepted by equipment users as preferred construction.

For whatever purpose you plan to use Stainless Steel — whether to insure superior mechanical performance, greater endurance or permanent beauty — you can obtain these qualities at their best in U·S·S Stainless Steel. This service-tested, perfected Stainless is available not only in many different analyses to cover practically every application and fabricating requirement but is produced in the *most complete* range of forms, sizes and finishes obtainable anywhere. Our stainless steel specialists will gladly go into the economics of its application with you.

EVERY SUNDAY EVENING, United States Steel presents *The Theatre Guild on the Air.* American Broadcasting Company coast-to-coast network. Consult your newspaper for time and station.

U·S·S STAINLESS STEEL

SHEETS · STRIP · PLATES · BARS · BILLETS · PIPE · TUBES · WIRE · SPECIAL SECTIONS

AMERICAN STEEL & WIRE COMPANY, *Cleveland, Chicago and New York*
CARNEGIE-ILLINOIS STEEL CORPORATION, *Pittsburgh and Chicago*
COLUMBIA STEEL COMPANY, *San Francisco*
NATIONAL TUBE COMPANY, *Pittsburgh*
TENNESSEE COAL, IRON & RAILROAD COMPANY, *Birmingham*
United States Steel Supply Company, Chicago, *Warehouse Distributors*
United States Steel Export Company, New York

UNITED STATES STEEL

standards. An international conference at Sevres, France, 50 years ago set the standard metric measurements for the world. Several times our platinum and iridium standards have been taken to France to see if they have changed—but change has been negligible.

Chrysler Tonic, Chrysler Div., Jan. 22, 1946

An interesting 1904 Maxwell car is on display in the automobile show room of Vaughn J. Snively in Baltimore. It is powered by a 2-cylinder engine that can still propel it at 18 m.p.h. It is frequently used in parades and has a large fan public. Vaughn has been offered $1500 cash for it—but scorns such offers with a sneer. This is undoubtedly one of the oldest cars in the country still in good operating condition.

The Aluminator, Lafayette Works, Aluminum Co. of America, Feb. 1, 1946

The tube mill recently shipped 13,600 lb. of aluminum tubing that will go into the manufacture of the much-publicized Reynolds International fountain pen that writes for two years with one filling of ink.

The Pegasus, Fairchild Engine & Airplane Corp., February, 1946

In no place is competition of war materials in post-war adaptations more keen than in the manufacture of rowboats and canoes. Descriptions have already been made of small boats of aluminum, magnesium and laminated plastics. Plywood is a fourth interesting material. The Duramold Co. at Jamestown, N. Y., has turned out a 12-ft. utility cartop boat, 48 in. wide from gunwale to gunwale. With buoyancy over 1200 lb., it leaves 6 to 8 in. of freeboard, with 6 persons aboard, the boat weight being 68 lb. Conventional boats that size weigh 112 to 200 lb. The plywood boat is skin-stressed, eliminating necessity for heavy ribs. The seats follow bridge-building principles, supporting beams being thickest at the center where loads are greatest. The shell is of molded veneers, instead of bent plywood and plank type construction in conventional designs. The thermosetting phenolic resin finish is very efficient. It withstands 7 hr. of boiling against 15 min. for conventional spar varnish.

Aluminum News-Letter, Aluminum Co. of America, January, 1946

Thirteen aluminum spandrels which were destroyed last July 28 when an Army bomber crashed into New York's Empire State Building have been replaced by new castings made in the Cleveland works of Aluminum Co. of America. The same Alcoa foundrymen had cast the 5,704 original spandrels installed on the skyscraper when it first was opened in 1931. Although the damaged spandrels had taken severe punishment under the terrific impact of the crash, it was possible to weld together pieces of one of the broken spandrels to serve as a guide in making the pattern for the new castings. Examination of the shattered spandrels showed their finish and soundness to be in excellent condition after almost 15 years of exposure to the elements. The original 5,704 aluminum spandrels,

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which greatly reduce the dead weight that the building's framework would have to bear if heavier metals had been used, utilized 615,000 lb. of aluminum. Applications of aluminum in the Empire State Building, in addition to the spandrels, include a dirigible mooring mast covering, wing ornaments and windows, storefronts, entrances, doors, exterior and interior trim, radiator grilles, and elevator cab trim.

Bakelite Review, Bakelite Corp., January, 1946

The extensive studies of the National Bureau of Standards on steel pipes, coated with all sorts of clears, enamelled, hot melts and wrapped coatings, and buried in various types of corrosive soils for 4 to 6 years, showed that phenolic resin baking coatings were practically unaffected, even to retaining high gloss after cleaning.

Meetings and Expositions

AMERICAN GAS ASSOCIATION, industrial and commercial gas conference. Toledo, Ohio. March 29-30, 1946.

AMERICAN SOCIETY OF MECHANICAL ENGINEERS, spring meeting. Chattanooga, Tenn. April 1-3, 1946.

SOCIETY OF AUTOMOTIVE ENGINEERS, spring meeting. New York, N. Y. April 3-5, 1946.

AMERICAN CHEMICAL SOCIETY, spring meeting. Atlantic City, N. J. April 8-12, 1946.

AMERICAN SOCIETY OF TOOL ENGINEERS, annual meeting and exposition. Cleveland, Ohio. April 8-12, 1946.

MACHINE TOOL FORUM, annual meeting, Westinghouse Electric Corp. Pittsburgh, Pa. April 9-10, 1946.

ELECTROCHEMICAL SOCIETY, spring meeting. Birmingham, Ala. April 10-13, 1946.

NATIONAL PLASTICS EXPOSITION. New York, N. Y. April 22-27, 1946.

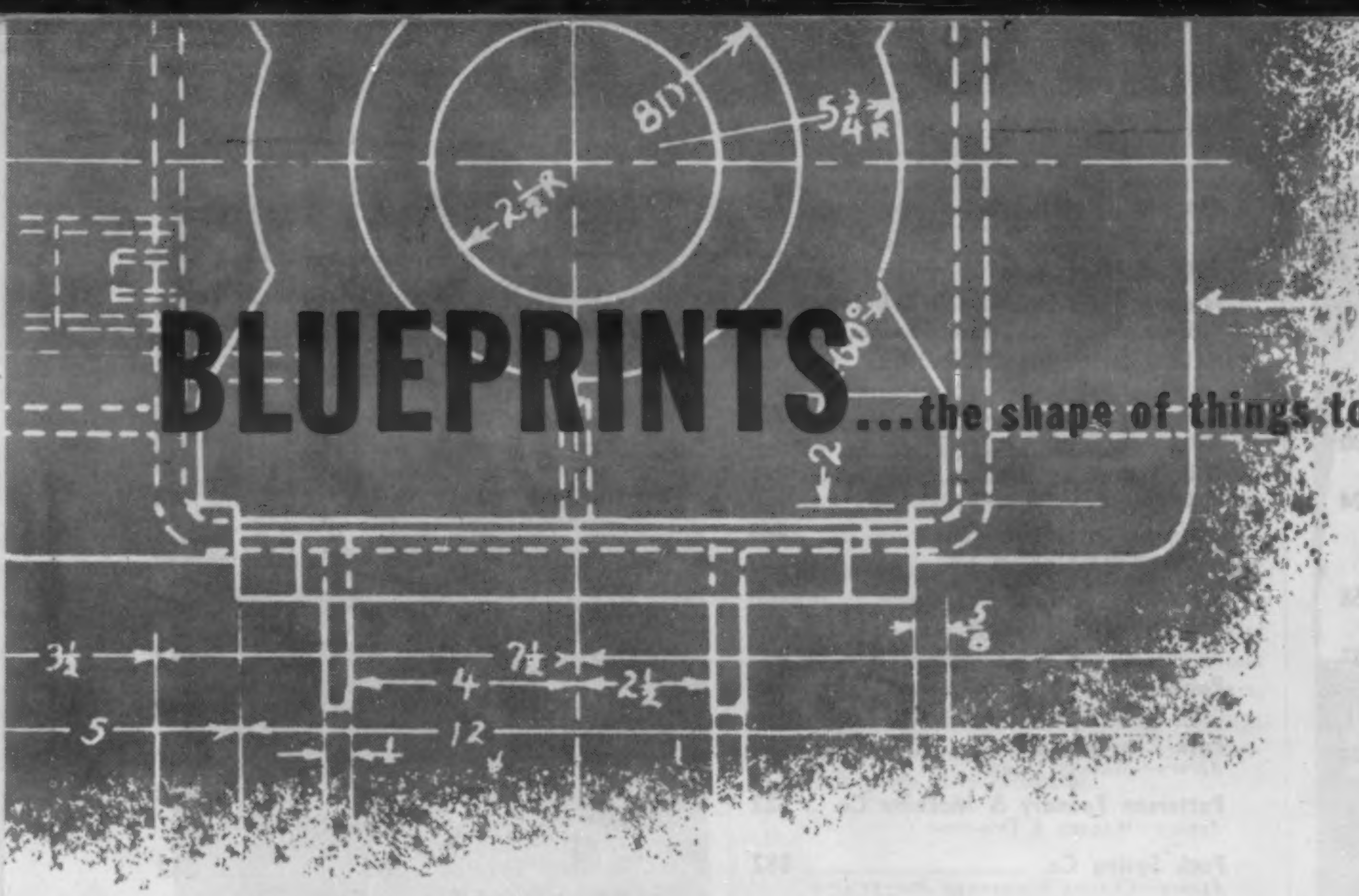
OPEN HEARTH STEEL AND BLAST FURNACE & RAW MATERIALS CONFERENCE, annual meeting. Chicago, Ill. April 24-26, 1946.

AMERICAN CERAMIC SOCIETY, annual meeting. Buffalo, N. Y. April 28-May 1, 1946.

AMERICAN FOUNDRYMAN'S ASSOCIATION, annual meeting. Cleveland, Ohio. May 6-10, 1946.

NATIONAL MARINE EXPOSITION. New York, N. Y. May 20-25, 1946.

AMERICAN IRON & STEEL INSTITUTE, general meeting. New York, N. Y. May 23, 1946.



BLUEPRINTS ...the shape of things to come

Magnesium: Grain Size and Porosity

Until recently the only method commercially available for insuring fine grain size in castings of many magnesium alloys was to superheat the melt several hundred degrees F, cool to casting temperature and pour promptly. Soon it will be standard practice to add certain carbonaceous materials to the melt at ordinary temperatures, a much easier and cheaper process. A porosity problem in magnesium alloy castings is being solved. Remember how organic sealing compounds were being used, such as tung oils, linseed oils, alkyd resins, etc? Throw these out the window. Fluxing the molten metal with chlorine will reduce the concentration of hydrogen which made the porosity during the solidification of the metal.

Aluminum Foil

Since prices of pig lead seem headed upward while aluminum prices are stable and may even decline, the prospects are for aluminum foil to supplant lead foil. A pound of aluminum naturally makes more foil than the equivalent weight of lead. New ways of making aluminum foil better and more cheaply have developed. The aluminum price is stable at 12c per lb. while American lead is 6½c as against a world price of 7c or more.

Plastic Automobile Bodies

One hears much about coming plastic and Fiberglas bodies for automobiles. Watch for fast developments. One such material is "Conolon," made by impregnating cellulose or Fiberglas fibers with a combined thermoplastic and thermosetting resin. It costs $1.58 to $3.93 per sq. yd. This low pressure plastic laminate has greater strength, yet less weight, than aluminum alloys. It will be used in a California-made automobile, with 2-cylinder aircraft engine, fluid-drive coupling, independent wheel suspension and no-shift gears—all selling at under $600.

Melting and Casting Aluminum

Expect hereafter larger open-hearth furnaces, up to 70,000 lb. of molten metal, for melting aluminum alloys instead of the 20,000-lb. jobs of prewar. As satisfactory metal can be produced at high melting rates as at low. Coal will be more widely used as fuel in place of coke. Low frequency electric induction melting used in Europe will become prevalent here. Zircon refractories are not wet by molten aluminum and will be popular. Good ways have been found for removing magnesium from aluminum scrap. Spectrography now better than ever allows for adjustment of composition in the molten condition.

Photo-Lofting

Why bother to laboriously duplicate hand drawings for this and that when you can impinge the wanted pattern on an object by photo-lofting? Tool manufacturing already uses widely photo templates and several prints of each drawing are made. Inspectors use photo-lofts for checking parts and assemblies, placing the detail part directly on the metal for comparison. Hundreds of assembly fixtures have been built directly on Masonite die stock sheets impregnated with the sensitizing emulsion and photo-printed. A huge 10-ton camera is used as a camera for copying and a projector for printing enlargements. Soon most any manufacturing business will be using photo-lofting. There will be jobbers who cater to small concerns that can't afford the large camera. Instrument panels, name plates, billboards—even neckties are a few possibilities. Tool engineers call it the most revolutionary development in a generation.

Ceramics to Coat Heat Appliances

New heat-resistant ceramics, used for military engines, will be used to coat automobile exhaust pipes, oil and coal burners, and similar everyday products.

Cast Nickel Range Tops

Where much cooking is done, such as in restaurants and hotels, range tops made of plain cast iron soon warp or sag, making an uneven heating surface, or fail completely by cracking. Some of the materials-conscious popular eating place proprietors are replacing such surfaces with cast nickel alloys, containing copper and chromium, which resist scaling, distortion and thermal shock. Perhaps the fussy diner will hereafter ask upon entering a strange eating place: "Do you have a nickel-copper-chromium range top?"